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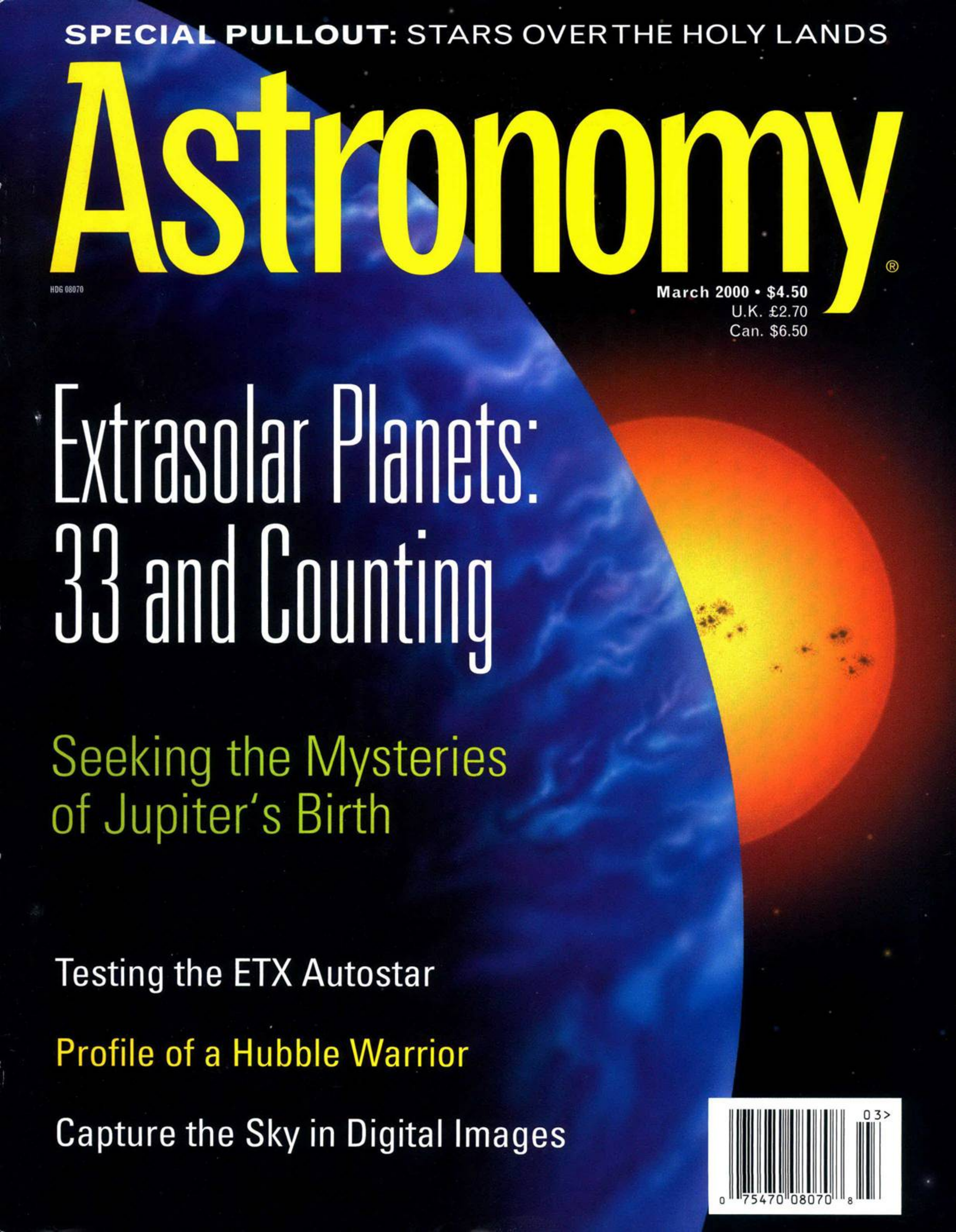

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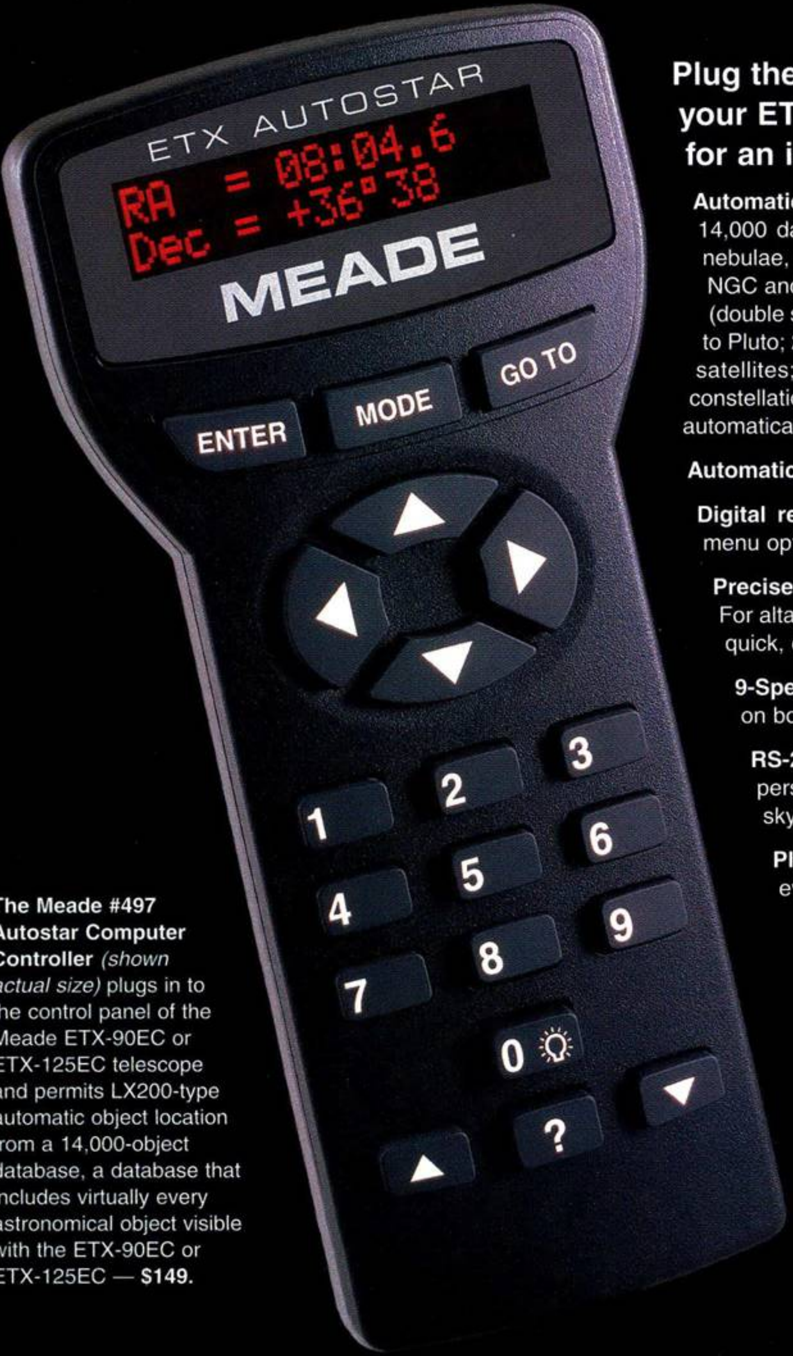

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(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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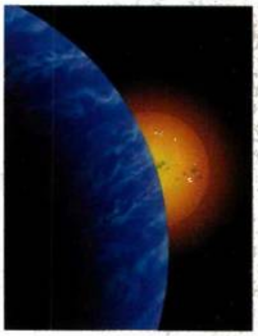

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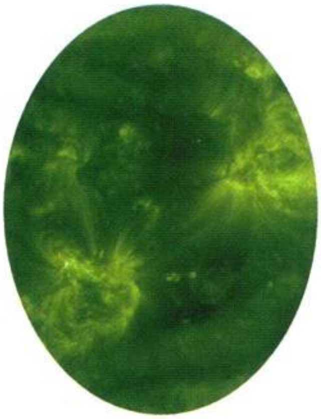

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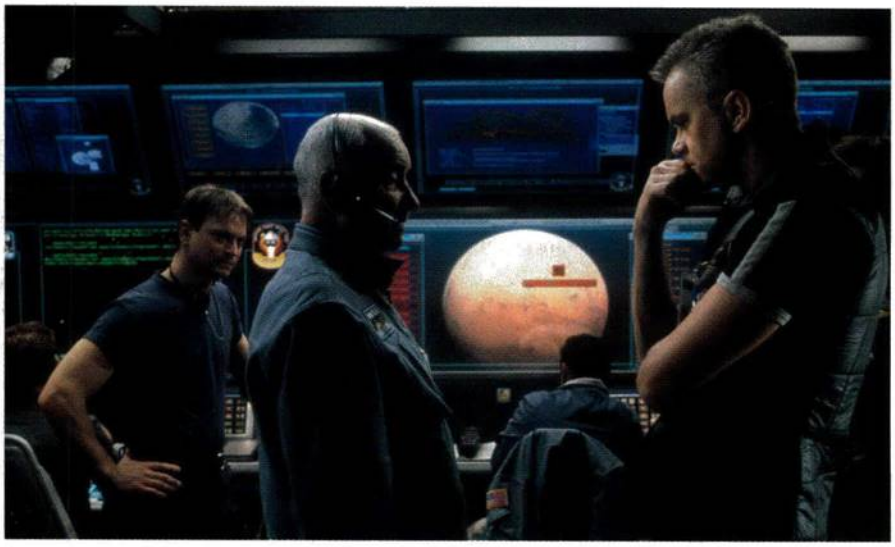
BY BONNIE BILYEU GORDON

Faster, Cheaper, Not Good Enough

It was something like going to a surprise party where the guest of honor never shows. The anticipated moment when the Mars Polar Lander could signal home from the surface of Mars for the first time (about 12:40 P.M. PST) passed with no signal. About 500 journalists and another 2,000 scientists, friends, and family members hovered around screens set up at the Jet Propulsion Laboratory (JPL) in Pasadena, California, on Friday, December 3, 1999, waiting for word of a perfect landing.

The press building included a lobby and two large rooms: one for press conferences with scientists and one where the reporters could work. The first held a split screen, a dais for a panel, about 300 chairs, and a three-tiered platform at the rear to support camera crews. One wall and part of the floor were painted to resemble Mars, and a model Lander and Deep Space 2, a microprobe, rested on the painted floor. The second room offered permanent desk space to preregistered writers, each with a name on it and a connection for telephone and computer. At the back of the work space, individual scientists could be interviewed in separate cubicles. A huge tent was set up to accommodate broadcast journalists outdoors. (It too included a model of the Lander.) Smaller tents sold Mattel's Lander models and t-shirts. A lot of attention had gone into the planning.

After the first 45-minute signaling period, the Lander still had not phoned home. The mission controllers kept stiff upper lips and made repeated statements that went something like: "Our inability to make contact with the Mars Polar Lander (MPL) during the first signaling period was not unexpected." By Saturday, you could substitute "day" for "period," and by Monday, "weekend" for "period."As of Tuesday, it was abundantly clear MPL was beyond NASA's control.



In a staged mission control room in a new film called *Mission to Mars*, actors Gary Sinise and Tim Robbins study their potential landing site on the Red Planet. Rob McEwan/Touchstone Pictures

The Lander was meant to set down safely near Mars's southern polar cap and begin a pattern of signaling Earth. NASA's Chief Administrator Dan Goldin was among the dignitaries in Mission Control, awaiting what surely could be a big success — one sorely needed after the failure of the Mars Climate Orbiter 10 weeks earlier. Reporters reacted quickly to the first threat of disappointment. At a 2 P.M. press conference, only about an hour after the first period of possible contact, several asked variations on the question "How long do we hold out hope?" Several camera crews pulled up stakes and left.

There would be several attempts to contact the Lander on December 3, and most people stayed around to watch.

One moment of pure jubilation broke out at about 8:30 P.M., when signals were heard from one of the Deep Space 2 probes meant to separate from the Lander and penetrate the surface of Mars. JPL scientists jumped up, smiling and shaking hands with Deep Space 2 Project Manager Sarah Gavit. Reporters raced to the press room from conversations in the lobby. Within a minute, a disembodied voice told us the signal was routine noise in the radio link.

By about 8:35 P.M., faces in the control room (and the press room for that matter) grew tense and grim. It had been a long day. Goldin, despite predictions to the contrary, stayed in mission control far beyond the first test period. He was there until 11:30 P.M. Friday, offering his support. Again he appeared on Saturday evening, looking like everyone else — ever more stricken.

Matt Golombek, project scientist for the highly successful Pathfinder mission to Mars two years ago, was cruising around among the reporters all day on December 3. As the news went from bad to worse, he tried not to look too smug.

By the time you read this, you will have already heard a dozen theories of what went wrong and another dozen on what will happen to NASA and planetary exploration because of MPL's failure. As early as 5 P.M. on December 3, while hopes for a successful landing were still relatively high, planetary scientist Carolyn Porco began to question

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the wisdom of NASA's current "faster, better, cheaper" philosophy. She told an audience that she has been involved for many years in the Cassini mission to Saturn. Cassini should arrive at its destination in 2004, and Carolyn said she hoped that all the scientists who first worked on it would still be alive when the satellite began to orbit. Hers is a slow mission and also a very expensive one, costing $3 billion so far. But she pointed out that Cassini has followed its complex marching orders perfectly, completing three flybys of other planets. Maybe, she said, it just costs a lot of money to do this kind of exploring and do it right.

Porco spoke at Planetfest, a big public party in Pasadena's Convention Center, thrown by the Planetary Society, JPL, the Touchstone Pictures movie *Mission to Mars*, and Oldsmobile, giving ordinary people the chance to share in the landing. On a workday in California, 10,000 people came to wait. Even after disappointment, thousands more came on Saturday and Sunday.

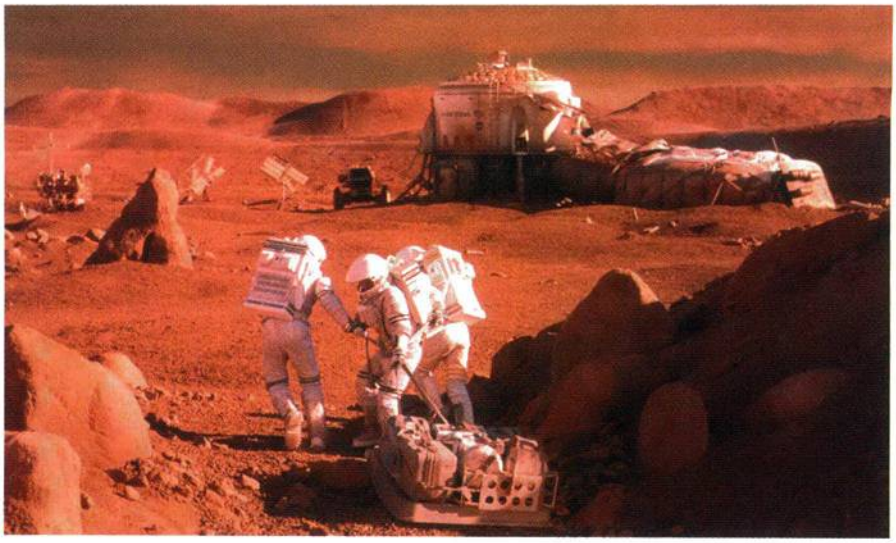
The wild enthusiasm shown by the media and the public over the little Sojourner rover that Pathfinder carried to Mars led everyone toward high hopes for this mission. Despite earlier failed attempts to explore Mars (by the Soviet Union and the United States), we were optimistic. And several movie makers jumped in for the ride. This month, Touchstone Studios introduces its swashbuckling *Mission to Mars* with Tim Robbins, Gary Sinise, and Jerry O'Connell as American astronauts sent to Mars to rescue survivors of an earlier mission. They arrive to find a half-crazed Don Cheadle, living alone in his wounded spacecraft and greenhouse.

JPL's Matt Golombek and astronaut Story Musgrave served as consultants to this movie, and NASA scientists at several levels pitched in to advise. Though any of them would say the movie isn't absolutely faithful to science, director Brian De Palma and producer Tom Jacobson went to great lengths to reach for accurate content. Filmed in Vancouver on 55 acres of red-painted volcanic rock, the movie looks as if it might capture the spirit of such an adventure. Meanwhile another movie, *Red Planet*, being produced by Warner Brothers, is scheduled to open in July 2000. Reports claim that this Val Kilmer vehicle includes at least one monster on the martian surface. And *Titanic* director James Cameron is working on a Mars stories for television. I wonder if all these projects will continue after two real-life Mars failures. Considering the public turnout at Planetfest, they probably will.

Movies are a complicated and expensive business; *Mission to Mars*, for example, cost about $120 million to make, while the Mars Polar Lander cost $165 million. However complex, movies are nothing so risky or dangerous as actually putting a satellite in orbit or a lander on another planet.

And, remember, so far even in this very bad year, NASA's success has been a whole lot better than that of baseball's heroic hitter Mark McGwire. He hit 65 home runs last season, but struck out 141 times. A

Mission to Mars was filmed on a 55-acre set in Vancouver, where volcanic rock was painted various shades of red to resemble the martian surface. Touchstone Pictures/*Mission to Mars*



TALKING BACK
FROM OUR READERS

Darkness Down Under

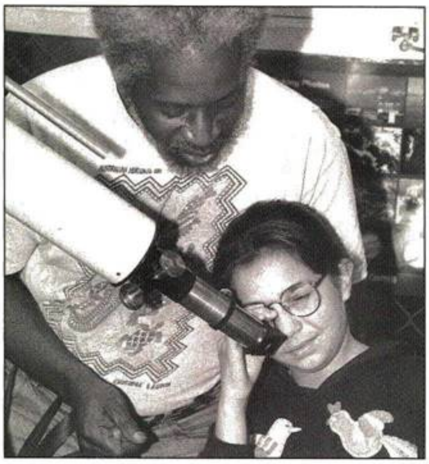
Australia's New South Wales State Government recently implemented a systematic policy to preserve dark skies around some of our most important telescopes. The "Orana (region) State Environmental Planning Policy" preserves an area around the Anglo-Australian Telescope in the northwest portion of my state. Among other things, this statute prohibits all development requiring electrical power for 18 kilometers around the telescope. It also gives the observatory's director veto power over future development proposals up to 100 kilometers away. — *David Campbell, Sydney, Australia*

Preserve Dark Areas

I love looking at the planets, stars, nebulae, clusters, and galaxies from my backyard on the Big Island of Hawaii. We don't have a major light pollution problem — yet. We need to preserve our dark areas. That way, the next generation will enjoy the same jewels of the cosmos. Let's set aside dark areas where our children can enjoy the breathtaking view of the sky that they deserve. Continued pollution of our night skies means the eventual loss of the splendor of the Orion Nebula or the awe of looking at the Andromeda Galaxy for the first time. Please help keep our skies dark, if not for yourself, then for future generations. — *Charles Holmes, Kailua-Kona, Hawaii*

All Together Now

A low-income housing complex in suburbia may not seem like the ideal setting for nightly sky watches, but *Astronomy*'s monthly sky maps, binoculars, and my rhyming dictionary are invaluable resources for bringing old and young people together. I mix poetry with astronomy to keep the child alive in all of us. Mindful that the ancients used rhymes so they could remember things, I use poetry not only as a teaching aid, but also to help make observing more fun and exciting for everyone involved.


Astronomical Society of the Pacific

Before I hosted my nightly sky watches, senior citizens felt isolated from the younger people in our development. Of course, the recent Jupiter/Saturn conjunction deserves some of the credit. We are fortunate to have the next millennium ushered in by this resplendent celestial event. — *David Cornell, East Meadow, New York*

Halloween Ritual

When people ask me why I chose to major in astronomy and physics, I think back to my childhood. On Halloween every year, my neighbor would set up his telescope and, in addition to giving out the usual sweets, would let the neighborhood children look at the moon. I remember the first time I ever saw the moon through that telescope. My dad had to lift me to the eyepiece. Peaks and craters stood out in detail. I was awestruck. For years, I looked forward to seeing the moon through that telescope. My neighbor's house became the first Halloween stop on my list. As I grew older, I bought my own telescope. My list of celestial objects lengthened, but the awe I experience in seeing them never diminishes.

To see astronomy's beauty requires assistance. I urge all of you to get involved with bringing the science of

(cont. on p. 18)

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SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

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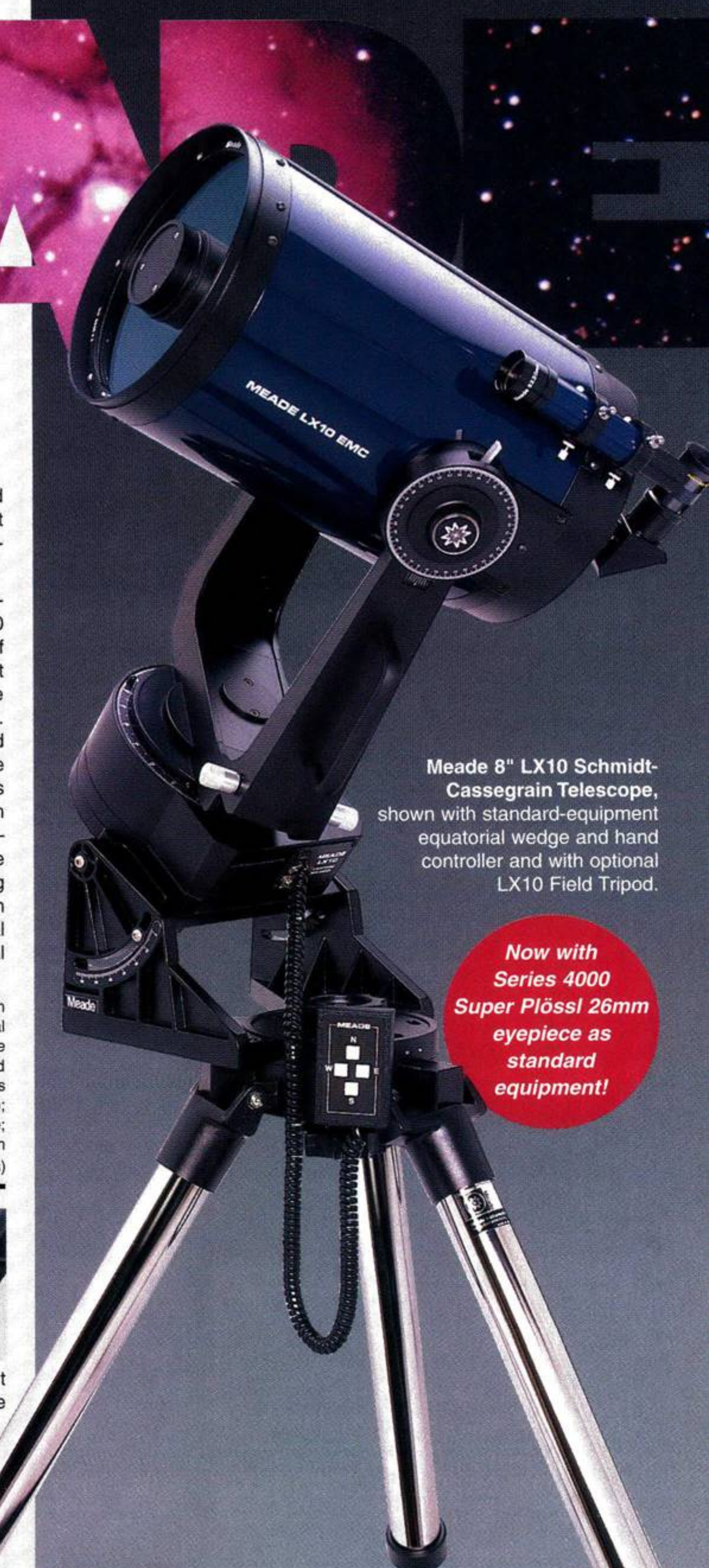

Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

ADVANCED PRODUCTS DIVISION

Meade Instruments Corporation

The largest-selling telescopes in the world. ☐ *A NASDAQ® company.*
6001 Oak Canyon, Irvine, California 92620 ☐ (949) 451-1450
FAX: (949) 451-1460 ☐ *www.meade.com*

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MEADE LX50

Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

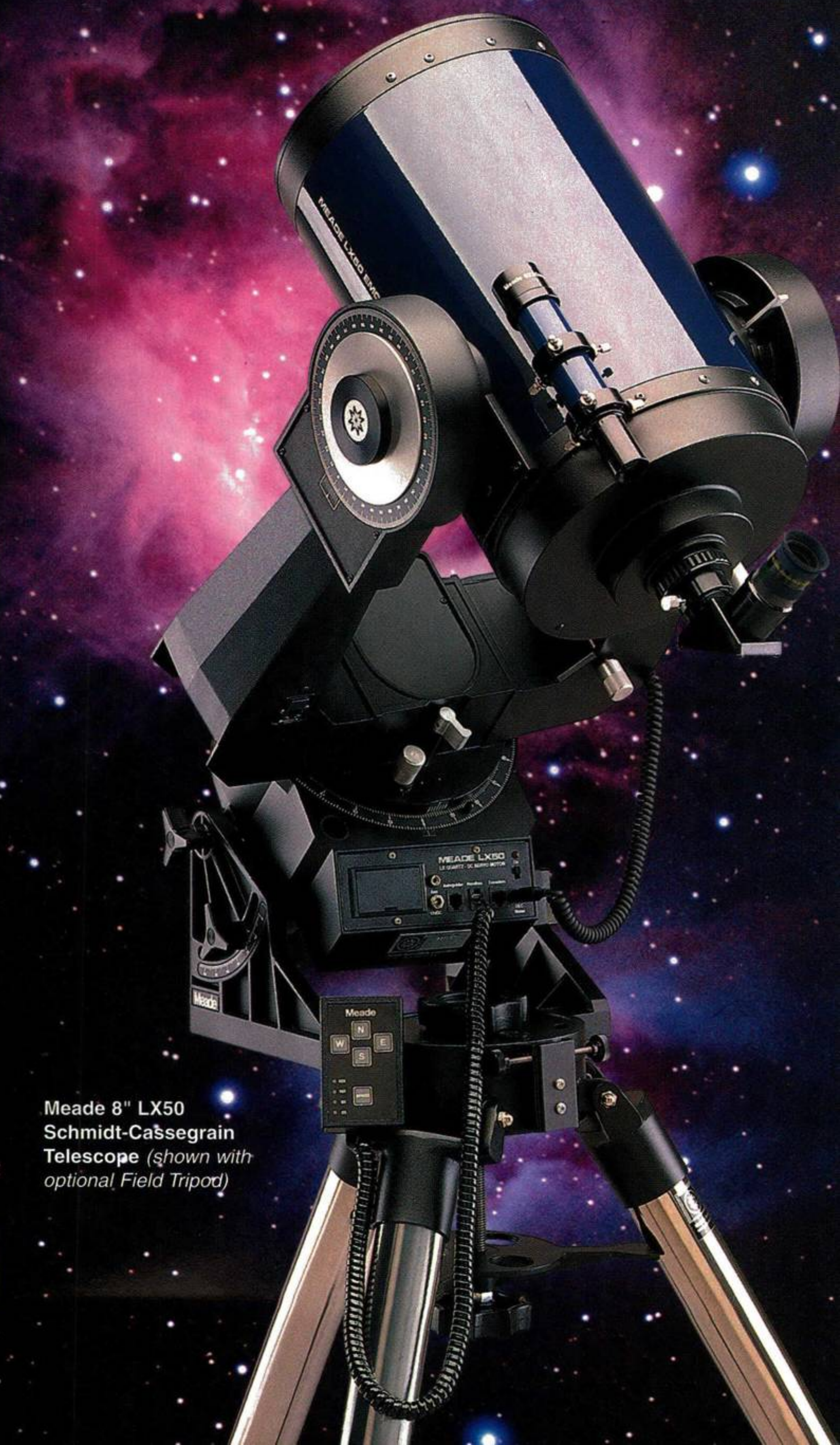
SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

Meade 10" LX200 Schmidt-Cassegrain Telescope

Prices shown are suggested U.S. national mail-order retail prices.

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. *Standard-equipment includes:*

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

Write, call, or fax Meade Instruments for your free copy of the 100-page Meade General Catalog.

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New Low Prices!

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STARFINDER™

DOBSONIANS & EQUATORIALS

Meade® Starfinder 10" Dobsonian ...*now only* *$449!*

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Complete with 1.25" rack-and-pinion focuser, 5 x 24mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Shown with optional #2010 Magellan I Computer System.

Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

Meade #77 2" Giant Rack-and-Pinion Focuser, with eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

Meade #637 6 x 30mm Achromatic Viewfinder, with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

Meade Series 4000 Super Plössl 9.7mm and 26mm multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple. **#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" — $295.** Packing & shipping in the 48 states—$15.

The lowest prices *ever* for Meade Starfinder Dobsonians — complete with these standard features:

Series 4000 SP26mm Eyepiece (1.25"): This $80 eyepiece permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities.

Professional-Grade Optical System with hand-figured optics of Grade-A fine-annealed Pyrex glass, *unlike the plate glass optics of other Dobsonians that can become thermally unstable.* Optics are multi-coated and meet the theoretical limits of resolution.

Rigid, Durable, Beautiful Dobsonian Mountings: Zero-backlash Teflon/Nylon bearings facilitate the quick location and easy tracking of celestial objects with extremely smooth motions of the telescope in both altitude and azimuth.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Strong, spiral-wound Sonotubes™ with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! Every Starfinder model opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets *in stunning high-resolution detail.* Starfinder Dobsonians are for visual observing; motor-driven Starfinder Equatorials may also be used for lunar and planetary photography, and even for limited deep-space photography.

Meade Starfinder Dobsonian Telescopes

Complete per specifications above:			
6" f/8	$249	**10" f/4.5**	449
8" f/6	349	**12.5" f/4.8**	795
		16" f/4.5	1195

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Note: Many manufacturers compromise telescope performance by using low-cost plate glass — glass which can become thermally unstable — in their primary and secondary mirrors, or else they charge a premium for Pyrex optics. *Meade Starfinder Dobsonian and Equatorial telescopes include Pyrex glass, exclusively, at no additional cost.*

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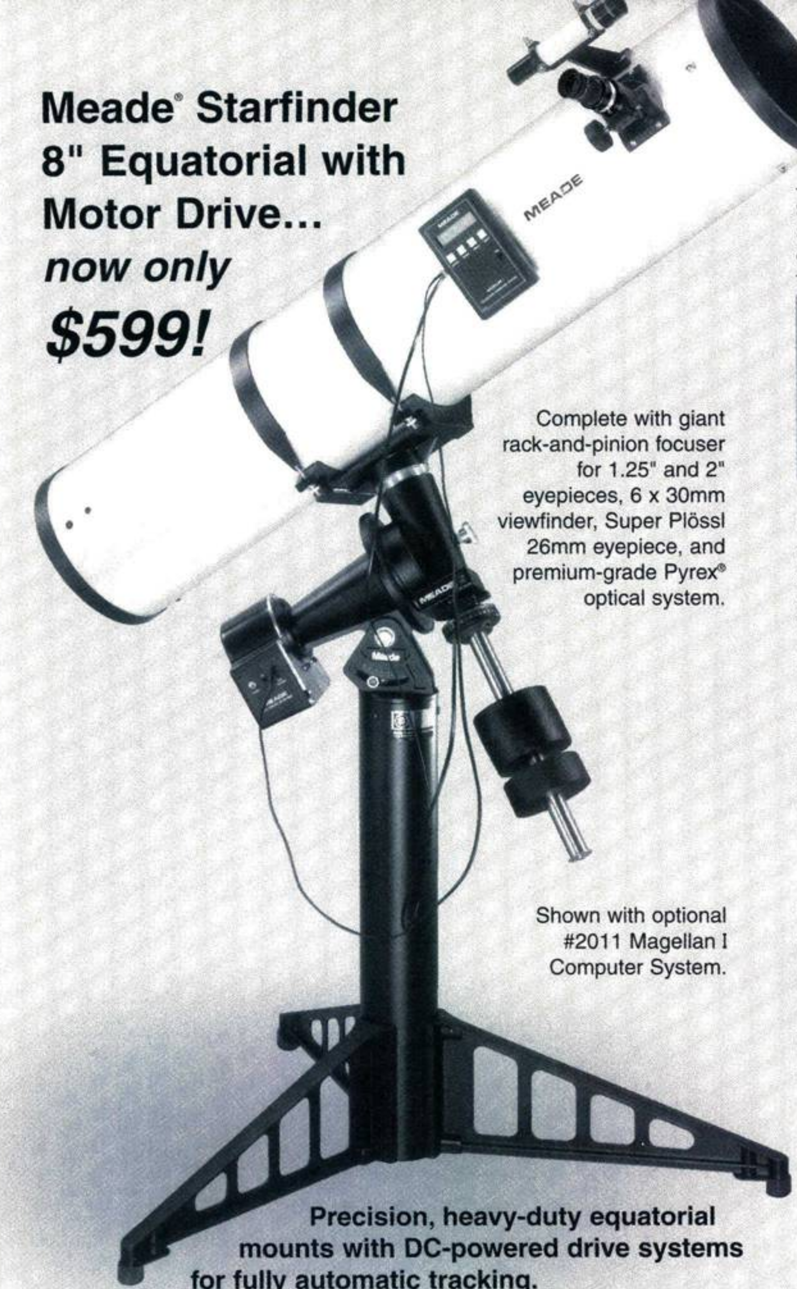
Meade® Starfinder 8" Equatorial with Motor Drive... *now only* *$599!*



Complete with giant rack-and-pinion focuser for 1.25" and 2" eyepieces, 6 x 30mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Shown with optional #2011 Magellan I Computer System.

Precision, heavy-duty equatorial mounts with DC-powered drive systems for fully automatic tracking.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Meade Starfinder Equatorial Telescopes

6" f/8	**$499**	**10" f/4.5**	**699**
8" f/6	**599**	**16" f/4.5**	**2695**

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

To Order any Starfinder model: contact your authorized Meade Advanced Products Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders/Info: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

Battery-Powered Cordless Drive System: For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries or from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 1.25" and 2" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 giant focuser.

Magellan I Telescope Computer System: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade Starfinder Equatorial 6", 8", or 10" . . . . . $295.
#2012: for Meade Starfinder Equatorial 16". . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for Starfinder Equatorial 6", 8", 10" . . . . 495.
#2019: for Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I – $15, Magellan II – $20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 2000 Meade General Catalog!

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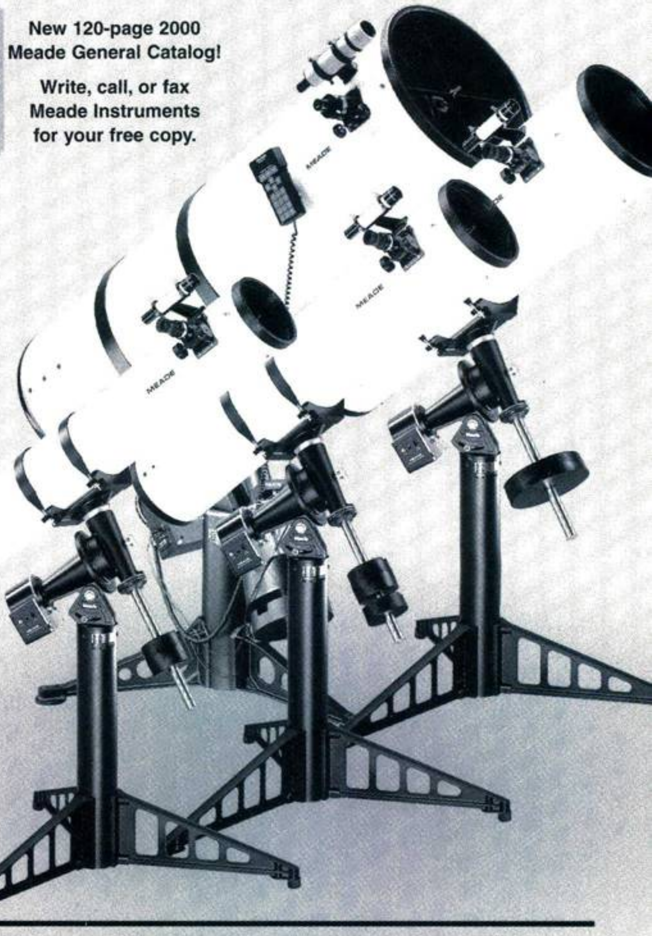

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RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

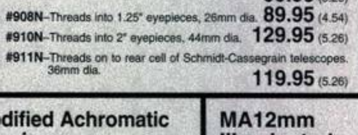
Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo),* an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)



Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

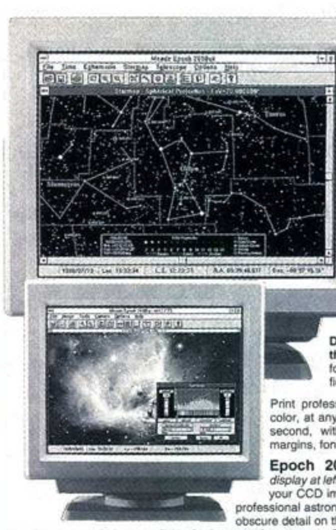
#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#647
MEADE
FLIP-MIRROR SYSTEM

Epoch 2000® Sky Software



The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

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EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$199**

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f/3.3 CCD FOCAL REDUCER

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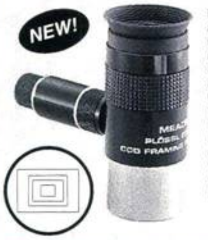
Plössl 25mm Illuminated Reticle CCD Framing Ocular



Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

$129.95 (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

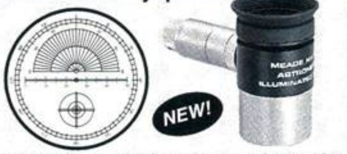
$49.95 (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

$34.95 (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25".

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For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, plus optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes two steel latches with key.

#774 Case for ETX-90 models:
99.95 (8.58)

#775 for ETX-125EC:
149.95 (13.38)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90 or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics.

$49.95 (3.86)

Advanced Field Tripod for ETX-125

#887: Yields *rock-solid* stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport.

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Tripod Adapter for ETX-125

Included with the #887 Tripod *(above)*, the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications.

#889 Adapter:
$69.95 (7.70)

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#883: Custom-designed by Meade specifically for ETX-90 and ETX-125 Astro Telescopes. Tripod height adjusts from 34" to 54", for seated or standing observations. Micrometric controls in azimuth and elevation permit precise polar alignment of the ETX fork mount. Tripod head tilts and locks to 90° for terrestrial applications. Telescope attaches to tripod in seconds with 2 thumbscrews. All-aluminum construction.

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Soft-padded Cordura-type carry bag with shoulder strap; permits storage of any 90mm ETX model, plus table tripod legs, eyepieces, other accessories.

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#1244 Electric Focuser for all ETX-90 models:
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astronomy to your community. On nights when you go observing, take a friend of any age along. The impression it leaves lasts a lifetime. How frightening to think that many people miss out on astronomical events simply because they were never introduced to the science. — *Kevin Kingsbury, Avon, Connecticut*

Got the Time?

Would you *please* be more specific when making time references on your web pages? For instance, if you say something will happen at 2:00 on the 17th, is that A.M. or P.M.? In which time zone? Instead, please use Greenwich Mean Time, Coordinated Universal Time or Zulu — times that are identical throughout the globe. — *Jon Croghan, Baker City, Oregon*

Greenwich Mean Time and Coordinated Universal Time are identical. Zulu Time is used by the military. Astronomy *always denotes a time reference somewhere in that section of magazine or web page. —* Astronomy editors

Dreaming Starts Early

I am writing to tell you that I enjoy your magazine very much. Each issue of *Astronomy* helps me in three ways: it enlightens me about things that are going on in outer space; it helps me with science projects at school; and it helps me toward my goal of becoming an astronaut. My "Science Journals" for my eighth-grade science class involve reading a scientific article, summarizing it, and writing my opinion of it. I use *Astronomy* articles for almost all my "Science Journals." I look to your magazine for the latest extraterrestrial updates.

I am sure that, at some point, nearly everyone dreams of becoming an astronaut. This is something I've wanted for a long time, and I believe that the best way for people to reach their goals is to start as early as possible. Your magazine helps me study astronomy and learn more, early in life.

Thank you for a magazine that will help me live out my dream! — *Joscelyne Sutton, San Francisco, California*

You First

Aries Keck's article on settling the solar system (December 1999) describes Robert Zubrin's Mars Direct plan. Although the objective is sound, the plan is flawed. Most of the $100-billion cost of these missions involves returning the astronauts to Earth.

A true program of settlement would omit a return trip. Instead, an up-front investment in technology could result in a self-sustaining facility, with a long-term operational life. Astronauts could renew the technology during subsequent missions.

I'm sure that of the six-billion-plus inhabitants of this world, we could find plenty of volunteers for a one-way trip, with the objective of remaining on and settling Mars. — *Bruce Appelbaum, Yorktown Heights, New York*

Ten Toes, Too!

Many times in the magazine and on the web, you refer to 1999 as the end of the century and millennium. That's incorrect — 2000 is the last year in this decade, century, and millennium. To see for yourself, count your fingers (assuming that you have ten like normal folks). Our calendar goes from B.C. to A.D. without a year zero. One B.C. was followed by 1 A.D. — *Mike Starkey, Placerville, California*

A readership dealing with light-years of distance should understand that a century-long or thousand-year-long interval of time draws to a close for more than 12 months. — Astronomy *editors*

Planned Retirement

Someday, I am going to retire to the wilderness just so I can view the full sky every night. Meanwhile, I'll get my monthly fix through the pages of *Astronomy*. Thanks for bringing the beautifully organized chaos of the universe to my imagination's doorstep. — *Darlene Grymkoski, Leander, Texas* ▣

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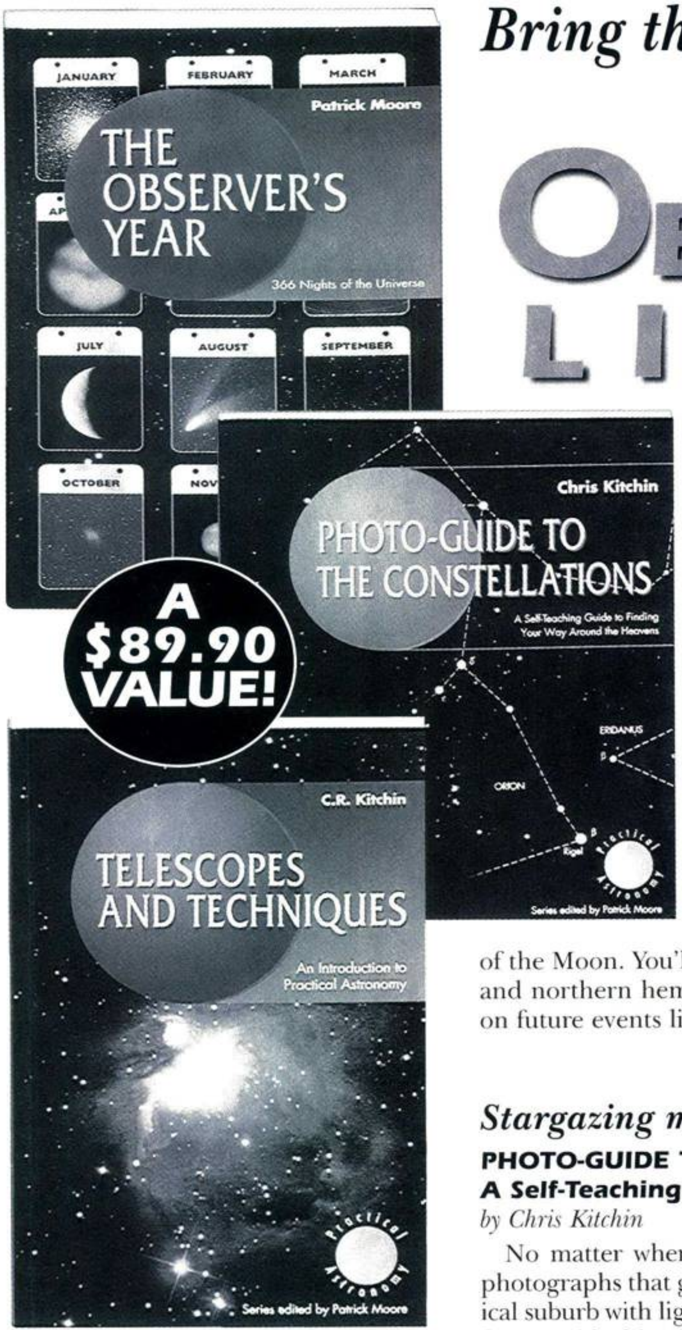
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CELESTRON TELESCOPES

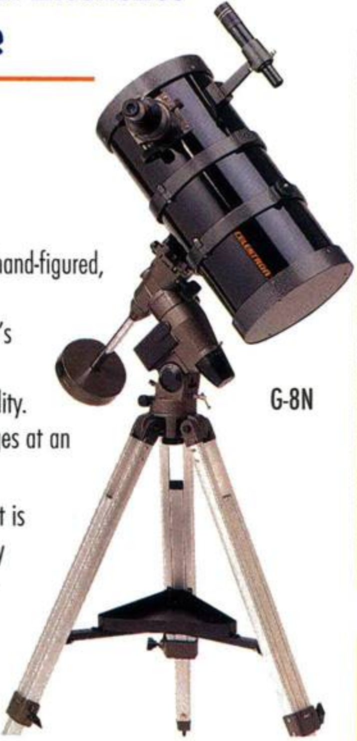
SCHMIDT-CASSEGRAIN • REFRACTOR • NEWTONIAN

Large Aperture Telescopes with Unequaled Optical Excellence + a Superb German Equatorial Mount = Real Value

G-8

OPTICS: **G-8 Telescope** – 8" f/10 Schmidt-Cassegrain
G-9¼ Telescope – 9¼" f/10 Schmidt-Cassegrain
G-8N Telescope – 8" f/5 Newtonian
CR-150 Telescope – 6" f/8 Refractor

Both of the Schmidt-Cassegrain systems are made in the U.S.A. and feature hand-figured, diffraction-limited optics along with Starbright® multicoatings. The fast (f/5) Newtonian is made to Celestron's uncompromising standards. The Newtonian's proprietary optical design incorporates an auxiliary correcting lens to reduce aberrations, flatten the field and allow a short tube design for added portability. The 6" refractor is a fully multicoated achromat which delivers excellent images at an incredibly low price.



G-8N

G-9¼

MOUNT: All four telescopes use the CG-5 German mount. The CG-5 mount is the newest generation of Celestron's German mounts which was designed by Celestron. Now, preloaded bearings in R.A. are standard (for added smoothness) which competitive models do not offer. Both axes of the equatorial mount have precision worm gears for extremely smooth motion and excellent tracking accuracy.

This heavy-duty mount easily delivers jitter-free images and the sturdy adjustable height aluminum tripod has excellent damping characteristics. A convenient deluxe accessory tray adds to the stability of the system.

CR-150

ACCESSORIES: Numerous accessories are available for these telescopes. Included as standard eyepieces – 25mm SMA - 1¼" (81x) on the G-8, 26mm Plössl - 1¼" (90x) on the G-9¼, 20mm Plössl - 1¼" (50x) on the G-8N, and 20 mm Plössl - 1¼" (60x) on the CR-150. The standard finderscope is a 6x30 with the G-8 and G-9¼ and a 9x50 with the G-8N and CR-150.

Some of the more useful accessories for these telescopes are the polar alignment scope (for fast polar alignment) and DC motor drives for automatic tracking of celestial objects. Celestron offers a choice of motor drives – a single axis (R.A.) or dual axis. They are powered by four D-cell batteries (not included). Both models include a hand controller with built-in drive corrector for astrophotography.

Computerize your telescope by adding the optional Advanced Astro Master® which is easily installed (use kit #93913 for CG-5 mounts). Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery. Contains an RS-232 serial interface to enable usage with programs like "The Sky" by Software Bisque.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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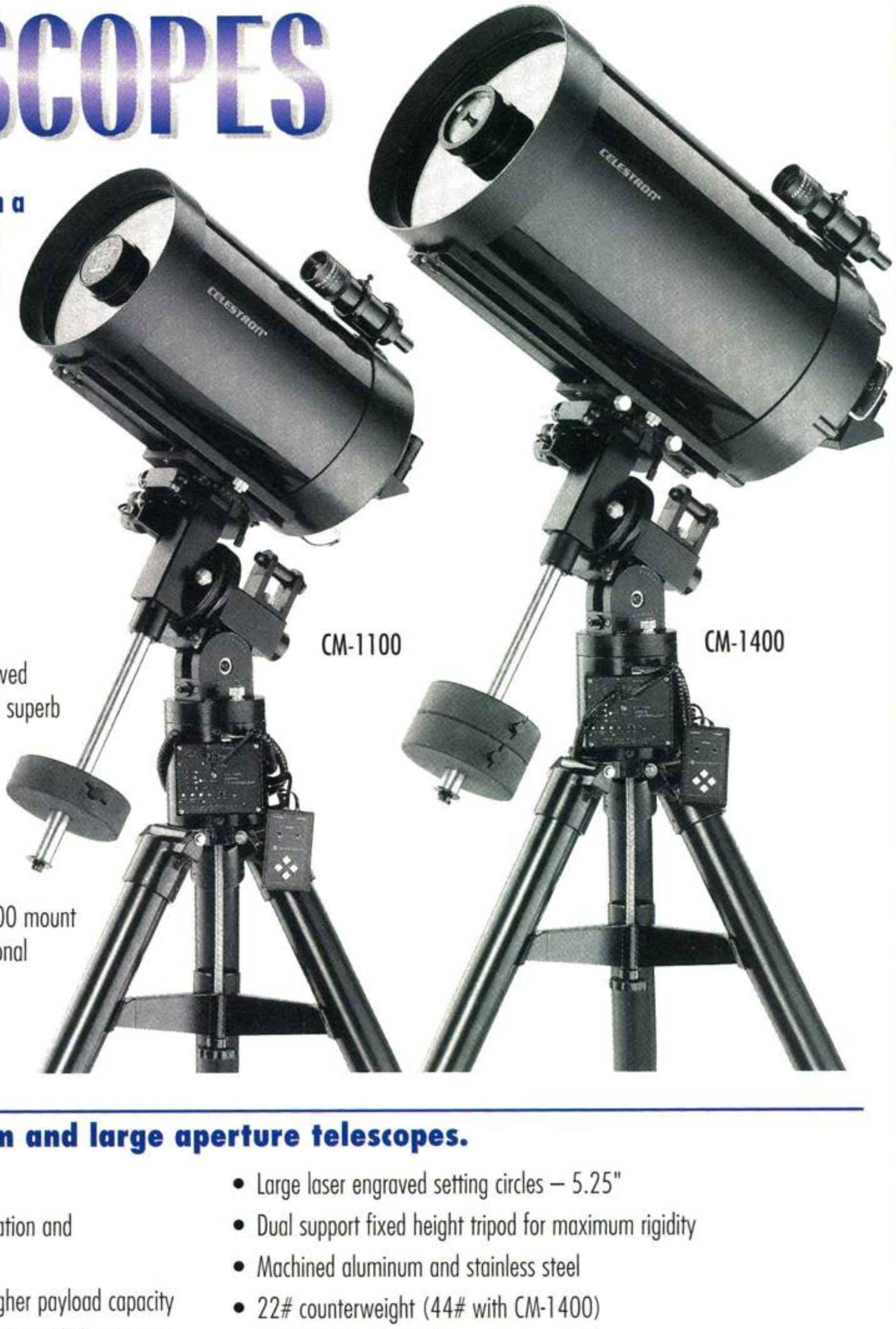
CM TELESCOPES

Unequaled optical excellence combined with a superb new German equatorial mount. The mount and telescopes are manufactured by Celestron in Torrance, California.

Professional quality telescopes for serious astronomical work yet portable enough for field use.



Optics:

- Legendary Celestron Schmidt-Cassegrains:
  11", 2800mm f/10 — CM-1100
  14", 3910mm f/11 — CM-1400
- Starbright® coatings

Lunar and planetary details are extraordinary when viewed through these instruments, and their large aperture and superb optics make for very exciting deep-sky observing of diffuse and planetary nebulae, open and globular star clusters, galaxies and binary stars.

Astrophotography and CCD imaging possibilities are endless. The 11" has been an astrophotography standard. Now the 11" and 14" coupled with the CI-700 mount raise the standards even higher. The 14" with the optional Fastar optics allows many ***unguided*** images at f/2!

THE CI-700 MOUNT

also sold separately for medium and large aperture telescopes.

- Manual slow motion controls in both axes
- Preloaded bearings in both axes for smooth axis rotation and gear mesh
- 1" solid centerless ground shafts in both axes for higher payload capacity
- 180 tooth main gear (5.625" dia.) allows for longer unguided exposures
- ½" dia. precision 303 stainless steel worm gears for super accurate drive accuracy
- Large laser engraved setting circles – 5.25"
- Dual support fixed height tripod for maximum rigidity
- Machined aluminum and stainless steel
- 22# counterweight (44# with CM-1400)
- Built-in polar axis finderscope is standard
- All these technical features deliver the smoothness, precision, refinement and controllability that you've always wanted in a fine mount.

DUAL-AXIS DC ELECTRONICS

- PEC (Periodic Error Correction)
- BC (Backlash Compensation) in declination
- Sidereal, solar, lunar, and King tracking rates
- .3x and .5x guiding rates
- 8x, 16x and 20x setting rates
- Hand controller operates simultaneously with all SBIG CCD imaging systems
- Car battery adapter
- Optional Advanced Astro Master® adapts easily with the specially designed hardware kit to computerize the telescope
- Standard accessories include: 9x50 finderscope, star diagonal and 26mm Plössl eyepiece.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron. **Visit our Web site at www.celestron.com**

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ACCESSORIES BY CELESTRON

The Celestron Accessories here are universal – use with virtually any telescope.

PLÖSSL EYEPIECES

In a recent *Sky and Telescope* review, Celestron's 1¼" Plössl eyepieces were rated as **top ranking**, and found to outperform many similar, but more expensive eyepieces. An exceptional value! Celestron offers these premium eyepieces at affordable prices, yet they're among the best designed and corrected eyepieces available. They're **multicoated** for enhanced contrast and all models are threaded to accept Celestron colored eyepiece filters. **Focal length with field of view:** 6.3mm (52°), 7.5mm (52°), 10mm (52°), 12.5mm (52°), 17mm (52°), 20mm (52°), 26mm (50°), 32mm (52°), 40mm (46°).

ULTIMA® EYEPIECES

These are Celestron's top of the line 1¼" eyepieces. They feature long eye relief and a wide field, and each air-to-glass surface is **fully multicoated** to enhance contrast levels. These special eyepieces are computer designed to keep visual aberrations to an absolute minimum. Recently, *Sky and Telescope* reviewed Celestron's Ultima® eyepieces and rated them **best in their class**, with greater contrast and image sharpness than the competitive models of other manufacturers. The inside surfaces and edges of all lenses are blackened, to keep out reflected light. Threaded barrels accept Celestron thread-in filters. **Focal length with field of view:** 5mm (50°), 7.5mm (51°), 12.5mm (51°), 18mm (51°), 24mm (51°), 30mm (50°), 35mm (49°), 42mm (36°).

LV EYEPIECES

These Vixen brand 1¼" eyepieces (6 to 8 elements) are a new breed, using the rare earth glass lanthanum in one of their field lenses, for almost total freedom from any visual aberrations. All focal lengths have a comfortable 20mm of eye relief. Even when using the 2.5mm LV eyepiece on a telescope, you'll have eye relief of 20mm! These eyepieces also feature **fully multicoated** lenses for optical excellence. **Focal Length with field of view;** 2.5mm (45°), 4mm (45°), 5mm (45°), 6mm (45°), 9mm (50°), 10mm (50°), 12mm (50°), 15mm (50°), 20mm (50°), 25mm (50°).

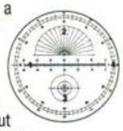
LV ZOOM EYEPIECE

This super premium 1¼" zoom eyepiece has a focal length of 8mm to 24mm. It is the finest zoom eyepiece for low to medium power observing. It's an excellent eyepiece that performs superbly, with **fully multicoated** surfaces. It offers an apparent field of 40° at 24mm and 60° at 8mm. Eye relief ranges from 15mm to 19mm.

CROSS HAIR EYEPIECE

This 1¼" eyepiece is of the Kellner design, with a focal length of 20mm. It's ideal for centering alignment stars when using digital setting circles or computerized telescopes. A useful all-around eyepiece for many applications, including terrestrial observing.

MICRO GUIDE EYEPIECE



This multifunction 1¼" guiding eyepiece features a laser-etched reticle with a built-in battery illuminator. The eyepiece is a **multicoated** 12.5mm Orthoscopic. Usage possibilities include: direct guiding on stars outside the center of the field of view; greatly improved off-axis guiding to capture much fainter, sharply focused guide stars without reducing limiting magnitude; and measuring position angles and separation of double stars. **Its finely etched micrometer scale** has gradations 50 microns apart and 15 microns wide. Included are: the eyepiece, built-in cordless illuminator with adjustable brightness control, batteries and instructions.

BARLOW LENSES

Celestron's premium quality .96" and 1¼" achromatic Barlow lenses are compact and lightweight. Both are under three inches long, with the 1¼" lens weighing in at 4 ounces and the .96" lens a mere 2 ounces! The clear aperture is 27mm on the 1¼" model, and 21mm on the .96" unit. The .96" Barlow is **fully multicoated** and the 1¼" lens is **multicoated**. The Ultima® Series Barlow (2x – 1¼") is an air-spaced, three element apochromatic design with a 27mm clear aperture. This lens features a very high quality, **fully multicoated** design. Amazingly compact and lightweight, it's just 5 ounces and 2¾" in length.

DIAGONALS

Celestron's Erect Image Diagonals are an Amici prism design. This design allows you to look into the telescope at a 45° angle, at images that are oriented properly, meaning the image is upright and correct from left to right. .96" to 1¼" models are available. Use of Celestron's hybrid .96" to 1¼" 45° Erect Image Diagonal on a telescope equipped with .96" eyepieces means greater versatility. This diagonal will allow you to use 1¼" eyepieces to obtain a larger field of view and better eye relief. A 90° 1¼" Erect Image Diagonal is available for those who prefer that angle. A 1¼" Star Diagonal (90°) is also available.

EYEPIECE FILTERS

Eyepiece filters are an invaluable aid in lunar and planetary observing. They reduce glare and light scattering, increase contrast through selective filtration, increase definition and resolution, reduce irradiation and lessen eye fatigue. Celestron's filters are made of high quality, solid plane parallel glass with excellent homogeneity. They're **antireflection coated** to prevent glaring and ghosting. All eyepiece filters are threaded to fit Celestron's, and most other manufacturer's, 1¼" eyepieces, and offer a full 26mm clear aperture. Filters available individually are: #12 Deep Yellow, #21 Orange, #25 Red, #58 Green, #80A Light Blue, #96 – 25% T, #96 – 13% T, Polarizing. In addition four different sets of four filters each are available.

1¼" POLARIZING FILTER SET

It's particularly useful for reducing glare while observing the moon, double stars, the planets and terrestrial subjects. You can vary the degree of transmission. By causing the amount of transmitted light to vary, the filters become, in effect, a continuously variable neutral density filter.

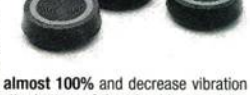
LPR FILTERS

Light Pollution Reduction (LPR) Filters are designed to selectively reduce the transmission of certain wavelengths of light, specifically those produced by artificial light. As a result, Celestron LPR Filters darken the background sky, making deep-sky observation of nebulae, star clusters and galaxies possible from urban areas. While blocking unwanted light, Celestron LPR Filters permit the transmission of more desirable wavelengths. This will improve your viewing of emission nebulae, both from urban and rural settings. They're also protected with a **broadband antireflection coating** to prevent ghosting and to improve contrast. They provide superior performance and contrast over competitive models. A 1¼" model threads into 1¼" eyepieces to work with virtually all telescopes.

MOON FILTERS

Celestron's Moon Filter threads into 1¼" eyepieces and aids in reducing the brightness of the moon and improving contrast, so greater detail can be observed on the lunar surface. The clear aperture is 21mm.

VIBRATION SUPPRESSION PADS



Telescope vibration is caused by windy conditions, an unsteady mount or tripod or even an accidental bump to the instrument, and results in reduced image quality. Celestron's set of three Vibration Suppression Pads **will reduce vibration time by almost 100%** and decrease vibration amplitude. The pads fit between the bottom of the tripod legs and the ground, a simple and functional solution to the problem of image disturbance.

NIGHT VISION FLASHLIGHT

Celestron's premium model for astronomy uses **two red LEDs** to preserve night vision better than red filters or other devices. Brightness is adjustable. Operates on a single 9 volt battery (included).

LENSPEN™

A superb new tool in optical lens cleaning technology. Perfect for cleaning binocular lenses, small aperture spotting scopes and telescopes, eyepieces, and other optical items. The LensPen™ comes with a handy retractable dust removal brush and a special non-liquid cleaning element, designed to never dry out. Safe and very easy to use.

SKY MAPS

Celestron Sky Maps are the ideal teaching guide for learning the night sky. You wouldn't set off on a road trip without a road map, and you don't need to try to navigate the night sky without a map either. Even if you already know your way around the major constellations, these maps can help you locate all kinds of fascinating objects. The front cover has a specially designed **luminous planisphere** that rotates to simulate the seasonal progression of celestial objects through the sky. When the planisphere is pre-exposed to light, star positions glow brightly against a dark background, mimicking actual constellations. More than a thousand stars and deep-sky objects are listed and charted.

PLANISPHERE

A simple and inexpensive tool for all levels of observers, from naked eye viewers to users of highly sophisticated telescopes. The Celestron Planisphere makes it easy to locate stars for observing and is a great planet finder as well. The Celestron Planisphere comes in three different models, to match the latitude from which you're observing: 20° to 40°, 30° to 50°, 40° to 60°.

TELESCOPE EQUATORIAL MOUNT–CG-3

A durable, rigid, German equatorial mount with a wooden tripod, offering both affordability and high quality. Designed as an excellent and inexpensive upgrade option when you're ready to move to a sturdier mount for your beginning telescope. R.A. and DEC setting circles, a latitude scale, slow motion controls and a handy accessory tray are included.

TELESCOPE EQUATORIAL MOUNT–CG-4

The CG-4 mount is a very rigid German equatorial mount. A counterweight, latitude scale, setting circles and slow motion controls on both axes are standard. The adjustable height aluminum, rigid tripod has **excellent damping characteristics** and a handy accessory tray. It is the same mount as used on Celestron HD telescopes and is a step up from the CG-3. Optional motor drives and a polar alignment finderscope are available.

TELESCOPE EQUATORIAL MOUNT–CG-5

The CG-5 EQ mount is the newest generation of Celestron's German mounts. Both axes of the equatorial mount have **precision worm gears** for extremely smooth motion. It is a step up from the CG-4. This **heavy-duty mount** delivers jitter-free images easily and the adjustable height aluminum, rigid tripod has excellent damping characteristics and a convenient accessory tray. Included are setting circles on both axes, slow-motion controls and latitude scale. An adjustable counterweight makes it easy to point, balance and use. An optional polar alignment scope for fast polar alignment as well as motor drives are available for easy tracking.

ALT-AZ PHOTO TRIPOD MOUNT

This heavy-duty mount is perfect for cameras with large telephoto lenses, and for spotting scopes and binoculars. If you already own a small telescope mount and are interested in one offering greater stability, the Alt-Az is an ideal upgrade. The adjustable wood tripod comes with two slow motion cables and is equipped with a ¼" x 20 photo head.

For more detailed information on these and other Celestron Accessories, contact a Celestron dealer or Celestron. Visit our Web site at www.celestron.com

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HD TELESCOPES

HEAVY-DUTY TELESCOPES OFFER MORE VALUE THAN YOU MIGHT THINK!

HD SERIES TELESCOPES – two refractors – an 80mm (3.1") with a focal length of 900mm (f/11) and a 102mm (4.0") with a focal length of 1000mm (f/10); two Newtonians – a 114mm (4.5") with a focal length of 900mm (f/8) and a 150mm (6.0") with a focal length of 100mm (f/7).

All models come standard with a 6x30 finderscope and a premium 20mm Plössl 1¼" eyepiece.

OPTICS – all **HD** series telescopes have diffraction limited, premium optics manufactured to Celestron's uncompromising standards. The star images are classic textbook Airy disks. The Newtonians have multicoated optics and the refractors are fully multicoated to provide higher light transmission yielding bright, high contrast images.

The refractors have very good color correction. The 150mm Newtonian uses a state-of-the-art proprietary optical design incorporating an auxiliary correcting lens to reduce various aberrations, flatten the field and allow the tube length to be shortened – and it is superior to most fast parabolas.

MOUNT AND TRIPOD – the **HD** telescopes use the CG-4 German equatorial mount. It is a precision, heavy-duty mount which is upgraded and much better than the older polaris mounts.

The precision worm gears are extremely smooth in motion and the tracking accuracy is excellent. Optional motor drives make astrophotography easy and fun.

The tripod is a sturdy, adjustable height unit made of aluminium and it includes a heavy-duty accessory tray.

In addition, the 102mm refractor is offered with a **HD** altazimuth mount. This mount is easy to use and has slow motion controls (flexible cables) on both axes to allow for quick and easy pointing and tracking.

The superb optics with rigid mount and tripod of the **HD** telescopes allow you to enjoy awesome details of our moon such as craters, rills and mountain ranges; Saturn and its rings; Jupiter with its belts and moons; Mars, Venus and Mercury; deep-sky objects such as galaxies, nebulae, double stars and star clusters.

C114-HD

C102-HD

C150-HD

C102-AZ

C80-HD

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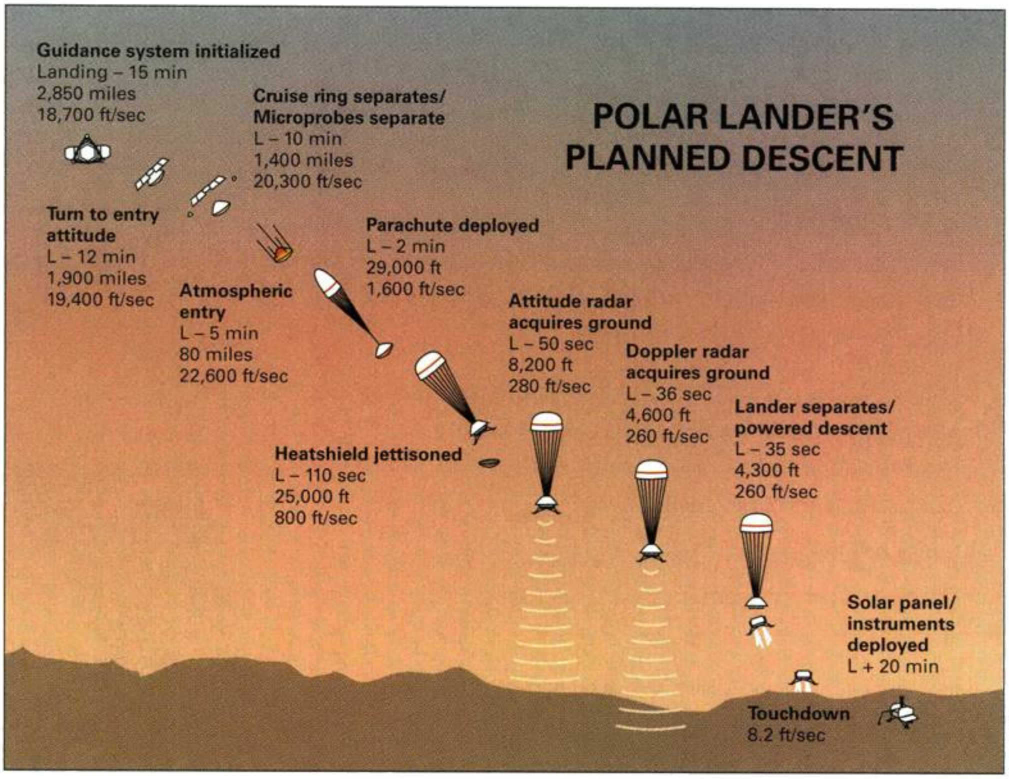
POLAR LANDER FAILS

Mars Exploration: The Sounds of Silence


POLAR LANDER'S PLANNED DESCENT
Guidance system initialized
Landing – 15 min
2,850 miles
18,700 ft/sec
Cruise ring separates/ Microprobes separate
L – 10 min
1,400 miles
20,300 ft/sec
Turn to entry attitude
L – 12 min
1,900 miles
19,400 ft/sec
Atmospheric entry
L – 5 min
80 miles
22,600 ft/sec
Parachute deployed
L – 2 min
29,000 ft
1,600 ft/sec
Heatshield jettisoned
L – 110 sec
25,000 ft
800 ft/sec
Attitude radar acquires ground
L – 50 sec
8,200 ft
280 ft/sec
Doppler radar acquires ground
L – 36 sec
4,600 ft
260 ft/sec
Lander separates/ powered descent
L – 35 sec
4,300 ft
260 ft/sec
Solar panel/ instruments deployed
L + 20 min
Touchdown
8.2 ft/sec

NASA/JPL

Mars Polar Lander was due to set down on December 3, but something happened to it during its descent or shortly after landing.

▶ Mars Polar Lander and its piggybacking Deep Space 2 microprobes kicked up a short-lived cloud of dust when they landed on the martian surface on December 3. But they have raised a swirling cloud of uncertainty over NASA's plans to explore the Red Planet.

As this issue went to press in mid-December, flight controllers at NASA's Jet Propulsion Laboratory (JPL) had not established contact with the $165-million Polar Lander, and they had given up all hope of hearing from the twin Deep Space 2 microprobes. Controllers would attempt communications through late December, but according to project manager Richard Cook of JPL, "The Mars Polar Lander flight team played its last ace. Our expectations for the success of the mission are remote."

The failures of Polar Lander and Deep Space 2 follow close on the heels of the Mars Climate Orbiter fiasco. That $125-million spacecraft failed to enter orbit around Mars last September because of poor management, inadequate staffing, and the failure of the prime contractor, Lockheed Martin Astronautics, to convert critical navigation data from English units into metric as specified in its contract.

NASA has established two independent committees to review the failures of Polar Lander and Deep Space 2. Until the committees report their findings in early 2000, engineers can only speculate whether the lander and microprobes succumbed to mechanical glitches, some unforeseen characteristic of the martian terrain, or plain bad luck. Navigation data relayed to Earth by the lander just 12 minutes prior to its entry into the atmosphere showed that it was on target. And a thorough investigation of the lander's design after the Climate Orbiter failed revealed no insurmountable design flaws.

Mars Global Surveyor's high resolution camera might be able to image the desk-sized Polar Lander — or what's left of it — on the surface. But because the camera has such a small field of view, it may be difficult to locate the lander, and the resulting images still might not reveal whether the lander crashed or touched down intact.

The Climate Orbiter/Polar Lander/Deep Space 2 triple whammy could affect NASA's plans to explore Mars. NASA is planning to send landers to Mars during the 2001, 2003, and 2005 launch windows. But NASA Administrator Dan Goldin is hinting that the 2001 mission may be delayed. The 2001 lander, which shares Polar Lander's basic design, will carry a small rover and perform three experiments to pave the way for human exploration. The 2003 and 2005 landers will deploy larger rovers that will collect rock and soil samples for later return to Earth.

Like Polar Lander and the Viking landers of the 1970s, all three future landers are designed to use parachutes and braking thrusters to land softly on the surface. The 1997 Mars Pathfinder, on the other hand, cushioned its landing with airbags. With the 2001 lander well into development, its design is unlikely to change unless the mission is postponed.

The failures also represent a major scientific loss. Climate Orbiter was programmed to monitor Mars's climate and seasonal cycle for a full martian year

The Universe Is Full of Mysteries. Using NexStar™ Isn't One of Them.

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NexStar 5 is light years ahead of other computerized GOTO telescopes, with Auto Align to get you up and observing immediately and an enormous object data base that includes more than 18,000 celestial sights.

Our Star Pointer Finderscope lets you quickly find any object in the sky, while variable slew speeds provide easy tracking for observation and astrophotography. You can attach our Hand Controller to the telescope's unique fork arm, or hold it for remote operation. There's even a communication port so you can control the NexStar 5 from your computer.

NexStar 5 is designed to go with you anywhere and perform beautifully. The legendary 5" Schmidt-Cassegrain optical system with Starbright® multicoatings guarantee superb views. Best of all, our Tour Function automatically seeks out the most spectacular objects in a given month, while providing you with fascinating facts through the Hand Controller.

If you're looking for a telescope that makes astronomy pure joy and fun, there's no mystery about which one to choose. **Celestron's NexStar 5.**

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Find out more about NexStar 5, our other exceptional telescopes, and nearby dealers. www.celestron.com

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(almost two Earth years). Polar Lander would have looked for water ice and evidence of climate change in layered terrain 500 miles from the south pole.

The failures of these relatively inexpensive missions raise questions about Goldin's philosophy of "faster, better, cheaper." "We wouldn't have had this mission if we hadn't gone this route. But it is possible we have gone too far in that direction, and we need to back off a little bit and do slightly fewer missions but devote more resources to them," says Ralph Lorenz of the University of Arizona, a member of both the Polar Lander and Deep Space 2 science teams.

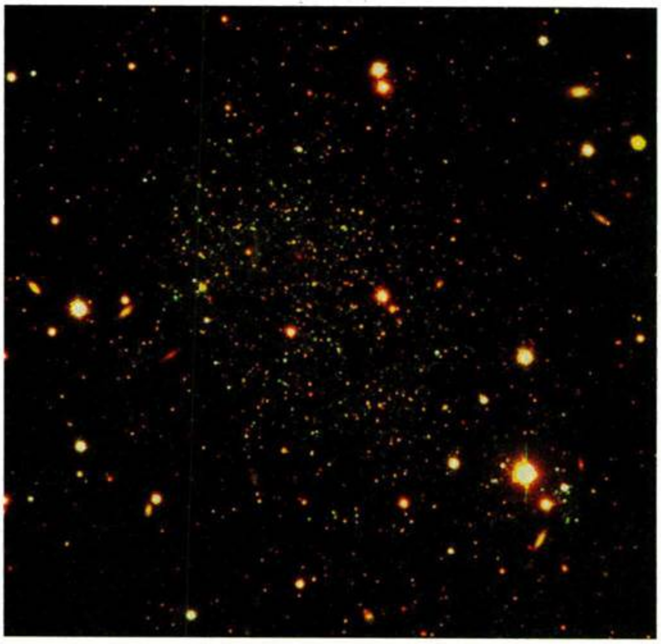
Jim Cutts, deputy director of the Mars Exploration Office at JPL, notes that NASA has succeeded three of the four times it has attempted to land on Mars, and that JPL could have built 20 Polar Landers for the cost of the Viking program. "It's painful when we have a failure, but we can rebound from this," he says. "Space exploration can't be done without risks, and landing on another planet is one of the riskiest things we can do."

— Robert Naeye

GALACTIC CANNIBAL

The Milky Way's Hunger for Galaxies

▶ Cannibalism is a way of life across the cosmos, as massive galaxies gobble up streams of stars from smaller neighbors — often taking in entire nearby galaxies. And such gravitational capture may have played an important role in making the Milky Way what it is today, at least in the hazy halo of stars that surrounds the galactic core.



The Milky Way Galaxy apparently cannibalized a dwarf galaxy early in its history. That galaxy likely looked similar to the Antlia dwarf seen here. European Southern Observatory

By studying a population of ancient stars in the halo, astronomers in the Netherlands have identified a group that they conclude arrived some 10 billion years ago as a dwarf galaxy, was drawn in and shredded, and had its stars strewn about. The streaming stars are "fossils," says Amina Helmi, of Leiden Observatory, of the cannibalized galaxy that probably was similar to the dwarf galaxy in Sagittarius.

The discovery is regarded as the first clear evidence that cannibalism of other galaxies helped build the architecture of the Milky Way during a time when the galaxy was developing. In a report in *Nature* last November, Helmi also concluded that perhaps 10 percent of all the ancient stars in the region of study in the halo may have come from that ancient galaxy.

"It's very exciting because they can say it's a real feature they see," says Kathryn Johnston, an astrophysicist at Wesleyan University who studies the structure of the Milky Way.

Using observations from telescopes on Earth and the Hipparcos satellite, Helmi studied hundreds of ancient stars within about 3,000 light-years of the sun. Their relatively low abundances of iron indicate they formed long ago. With colleagues at the Max Planck Institute for Astrophysics in Germany, she found a dozen that streamed in a noticeable pattern. Computer models show that these old stars could have been thrown into motion by an ancient galaxy that hit the Milky Way.

Other astronomers had nibbled at similar studies in the past. That Helmi could discern both the distances involved and the three-dimensional motion of the stars in question make the argument particularly compelling, Johnston says. Astronomers knew as early as 1994 that the Milky Way is a cannibal today. That's when they found that the Sagittarius dwarf is being tugged by the Milky Way.

Helmi is now looking for other examples of ancient cannibalism. Such searches are necessary, Johnston says, adding: "This is just the beginning. We don't know how common these were."

— David Graham

GALILEO MISSION

A Hot Time on Io

▶ The Galileo spacecraft has survived two nearly suicidal plunges into Jupiter's radiation belts, returning the sharpest images ever of the giant planet's inner moon, Io.

The first of the two Io flybys came on October 11, when the spacecraft dipped within 380 miles of the moon's surface. Galileo recorded more than 100 erupting volcanos and revealed gigantic lava flows, huge lakes of lava, and towering, collapsing mountains. "It makes Dante's *Inferno* seem like another day in paradise," says Alfred McEwen of the University of Arizona, a member of the Galileo imaging team.

The new observations concentrate on three of the moon's most active volcanos: Prometheus, Pele, and Loki. Prometheus, the "Old Faithful" of Io's volcanos, apparently has been erupting continuously ever since it was discovered by the Voyager spacecraft two decades ago. Earlier, lower resolution images of the region taken by Galileo

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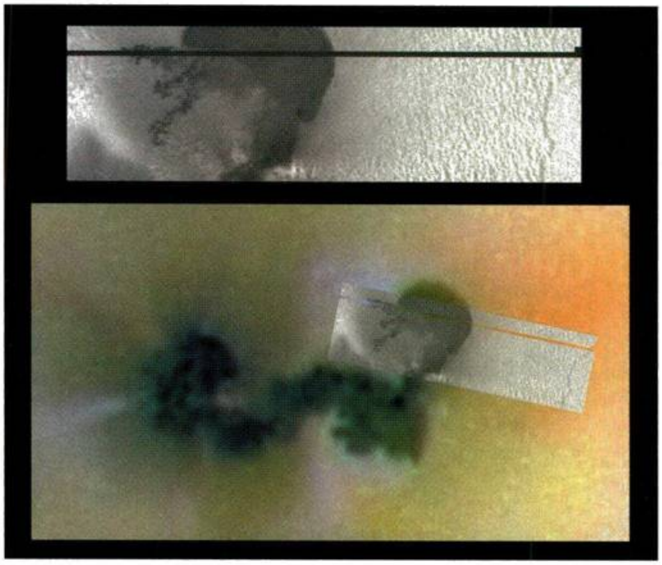
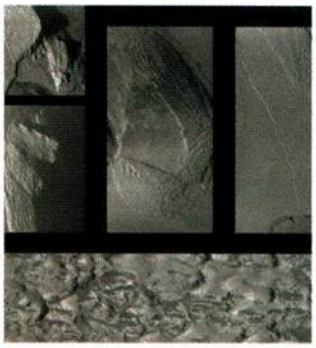




A high-resolution view of Io's Prometheus volcano overlays an earlier color image and reveals a caldera filled with lava (left). Galileo also photographed several tall mountains (above), which seem to be collapsing. NASA/JPL

showed a plume some 30 to 60 miles high erupting from a spot about 60 miles west of where Voyager saw it. The new observations help clarify what's going on.

Galileo's near-infrared mapping spectrometer shows two distinct hot spots that mark areas where hot lava flows on the surface. Images from the camera reveal numerous lava flows near the western hot spot and a caldera measuring 17 miles long and 9 miles wide near the eastern one.

Scientists thought the plume formed where lava erupts to the surface, but now they believe it arises at the far end of the lava flows. Molten rock apparently rises to the surface at the caldera and then travels westward through underground lava tubes before breaking out onto the surface again. The plume forms when this hot lava vaporizes liquid sulfur dioxide in an adjoining layer.

The volcano Pele is home to an intense hot spot that glows steadily at 2,700° Fahrenheit — a temperature not reached by earthly lavas in more than 2 billion years. Intermittent eruptions typically spread out and cool, but Galileo saw little cooler lava at Pele, implying that fresh lava must be erupting almost constantly. The camera also captured a thin, curving line — some 6 miles long and just 150 feet wide — of hot lava no more than a few minutes old. Planetary scientists suspect the line marks the edge of the lava lake, where solidifying crust breaks up along the caldera's wall.

Loki turns out to be the most powerful volcano in the solar system, generating more heat than all of Earth's volcanos combined. Galileo made a detailed temperature map of Loki that suggests its enormous lava lake is crusted over and perhaps a month to a year old. "Loki is repeatedly flooded by lava over an area larger than the state of Maryland," says Rosaly Lopes-Gautier of JPL.

Another surprise of Galileo's visit turned out to be the great height of its mountains. Ionian peaks reach up to 52,000 feet high, far higher than Earth's tallest. Paradoxically, they do not appear to be volcanos. Although planetary scientists have yet to figure out how they form, the Galileo images indicate how they may die. The concentric ridges that cover the mountains and surrounding plateaus suggest that huge landslides sculpt the terrain as the mountains collapse under the force of gravity.

Following this encounter, Galileo returned to Io on November 25. Results from the second flyby were still being transmitted to Earth as this issue went to press.

— Richard Talcott

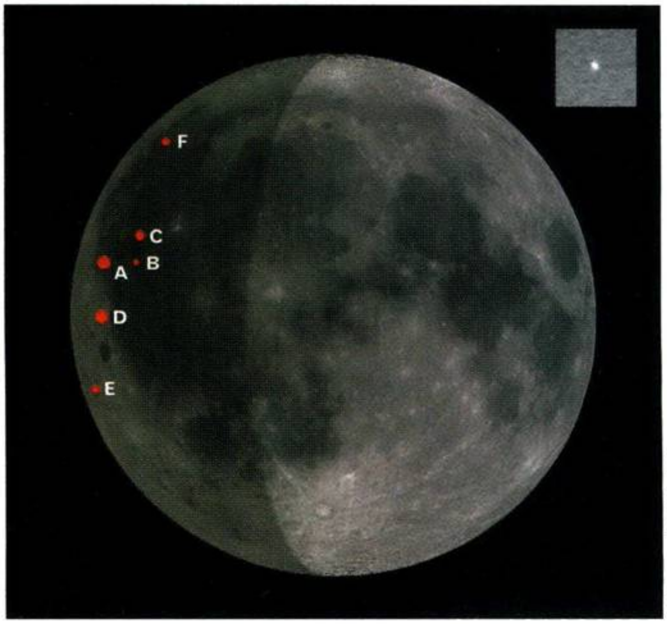
LEONID STORM

Leonid Meteors Strike the Moon

▶ When Earth passed through the debris of Comet Tempel-Tuttle on the night of November 17/18, observers around the world witnessed one of the best meteor showers in decades. The meteors, or "shooting stars," were the visual results of what happens when tiny dust particles slam into Earth's atmosphere at 45 miles per second and burn up.

Earth wasn't the only celestial object in the Leonids' crosshairs — comet debris rained down on the moon as well. Yet the moon lacks an atmosphere, leaving it short the one critical component needed to produce meteors. Or so it

At least six Leonid meteors hit the moon at the shower's peak on November 17/18 (positions are marked by the letters A–F). One of the brightest flashed briefly on this video frame (inset).



Both images: David Dunham

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Software Bisque 912 Twelfth Street, Suite A Golden, Colorado 80401 303.278.4478 would seem. But even a small particle traveling at 45 miles per second can pack a wallop when it hits the moon. The resulting flash of light could be visible on the moon's dark side — if anyone bothered to look.

Inspired by a NASA website that explored this possibility, David Dunham, president of the International Occultation Timing Association, orchestrated a campaign to get observers to monitor the moon's dark side at the peak of the Leonids. The effort paid off.

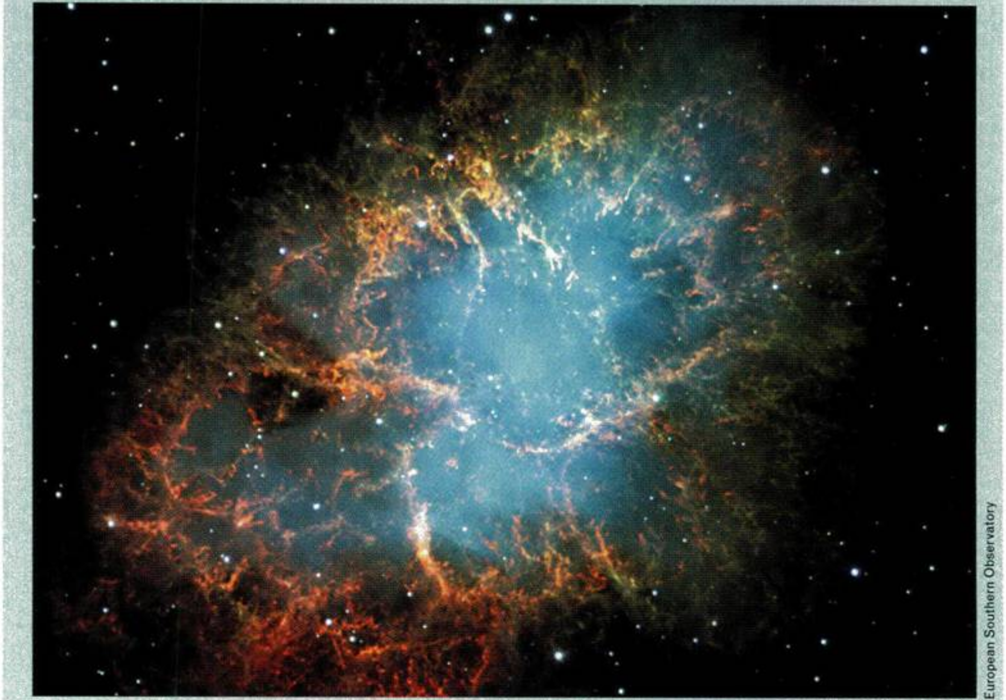
The first reported sighting came from Brian Cudnick of Houston, Texas, who saw a brief orange flash while observing through a 14-inch telescope. The 3rd-magnitude flash occurred near the center of the moon's dark side at 10:46 P.M. CST on the 17th. Cudnick told Dunham, who searched a videotape he had made that night through a 5-inch telescope. There the flash was, just as Cudnick described.

During the next couple of weeks, careful study of additional videotapes revealed five more definite impacts. Pedro Valdés Sada of Monterrey, Mexico, discovered two using his 8-inch telescope, while David Palmer of Greenbelt, Maryland, found three more with his 5-inch scope. All were confirmed by sightings on other videos.

The flashes ranged in brightness from 3rd to 7th magnitude and each lasted only a fraction of a second, appearing bright on one video frame, considerably fainter on the next frame 1/60 of a second later, and disappearing on the subsequent one. All occurred between 10:05 P.M. EST on the 17th and 12:15 A.M. EST on the 18th, peaking about three hours after the peak seen on Earth. Not surprisingly, the waning crescent moon then trailed Earth in its orbit by approximately three hours.

Researchers don't know how large the meteors were, with estimates ranging from several hundred pounds down to a pound or so. The resulting craters could be as much as 50 feet across, far too small to see from Earth. However, any craters might be found by comparing images from the Japanese Selene spacecraft, scheduled for launch in 2003, with Apollo and Lunar Orbiter images. — R. T.

EUROPEAN SOUTHERN OBSERVATORY


European Southern Observatory

ALTHOUGH THE EXPLOSION TOOK PLACE nearly a thousand years ago and 6,000 light-years from Earth, the supernova still paints a vivid picture in our sky. Known as the Crab Nebula (Messier 1), the remnant of this stellar explosion is a turbulent mixture of gas and dust with twisting filaments of ionized gas. In this new composite image taken with the Very Large Telescope at the European Southern Observatory in Chile, the green color comes predominantly from hydrogen atoms ejected in the explosion and the blue from high-energy electrons moving in the nebula's magnetic field. A pulsar that spins 30 times a second — the collapsed remains of the exploded star — continuously ejects and accelerates these electrons to near the speed of light. The pulsar can be seen near the center of the nebula, the lower-right member of a pair of close stars just left of a small arclike feature.

EARLY UNIVERSE

When Galaxies Collide

▶ A three-year survey of 123 ultraluminous infrared galaxies (ULIRGs) conducted with the Hubble Space Telescope has found that 30 percent of them may be the result of three, four, or even five galaxies crashing into one another. Astronomers previously *thought* that only pairs of galaxies were interacting in ULIRGs. The images reveal complex knots that closely resemble computer simulations of multiple galaxy collisions.

The Infrared Astronomical Satellite (IRAS) first detected ULIRGs in the early 1980s. They are brilliant at infrared wavelengths, glowing 100 times brighter than the Milky Way. This strong infrared output results from widespread star birth triggered by the collisions. As the hot, newborn stars shine, surrounding dust absorbs and then reradiates that light at longer (infrared) wavelengths.

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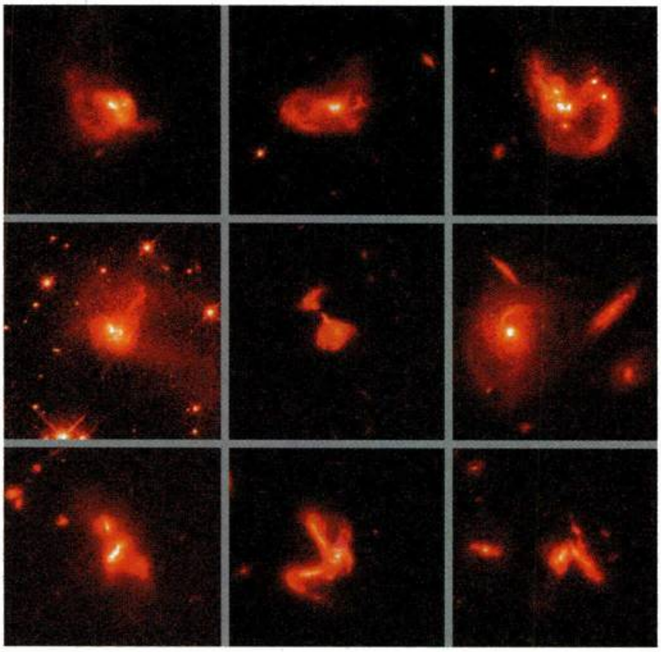


Kirk Borne (Raytheon and NASA/GSFC), et al. and NASA

As multiple galaxies crash into each other, they create a tangled clump of matter, a burst of new stars, and prodigious amounts of infrared radiation.

"We are seeing the final stage of the hierarchical evolution of the universe, where small fragments coalesce to build ever bigger objects," says Kirk Borne of NASA's Goddard Space Flight Center. "We see matter ripped out of galaxies in the form of long tails of stars, and matter contracting in the form of multiple nuclei crowded together. In some we see a 'nest' of galaxies where they all coalesce."

The forefathers to these galactic pileups may be Hickson compact groups of galaxies. Hickson groups are tightly formed clusters of at least four galaxies that appear isolated from other galaxies. Borne plans follow-up spectroscopic observations that will measure collision speeds and possibly give further proof that more than two galaxies are interacting.
— Andrea Gianopoulos

AN ACTIVE MOON?

Neptune's Triton a Mere Babe

▶ When Voyager 2 zoomed by Neptune's moon Triton at close range in 1989, it imaged few impact craters and no large impact basins. Generally, the more craters on a surface, the longer the surface has been accumulating impacts. So a paucity of craters implies a youthful age. Based on the estimated rate of impacts from comets coming in from the Oort Cloud (a vast realm of cometary nuclei thousands of astronomical units from the sun), astronomers initially estimated that the average age of Triton's surface was about 1 billion years — only one-fourth the age of the solar system.

But according to new calculations by planetary scientists S. Alan Stern of the Southwest Research Institute in Boulder, Colorado, and William McKinnon of Washington University in St. Louis, Missouri, Triton's surface is even younger than that — perhaps only 100 million years on average and possibly less than that.

Stern and McKinnon realized that Triton would be pummeled by more than just Oort Cloud comets. In the 1990s, astronomers have discovered about 200 objects in the Kuiper Belt — a disk of small, icy bodies orbiting the sun beyond Neptune. Because less than one percent of the Kuiper Belt has been searched, there must be tens of thousands of large objects and billions of comets in the Kuiper Belt. Stern and McKinnon found that for every time Triton is smacked by an Oort Cloud comet, the moon should be hit by roughly 10 Kuiper Belt objects.

"It's a no-brainer in retrospect," comments Stern. "In 1990 the Kuiper Belt hadn't been discovered. But if you leave out the major source of impacts, you'll clearly underestimate the cratering rate and overestimate the age."

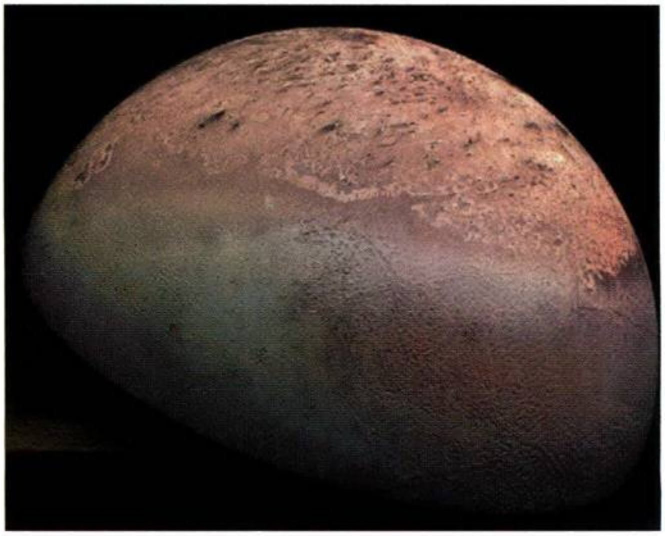
Triton's youthful countenance is a major surprise because small worlds cool faster than large ones. With a diameter of only 1,680 miles (only 78 percent that of Earth's geologically dead moon), Triton should have cooled off long ago. But if Neptune's moon was active 100 million years ago, it is probably still active today. "Triton was almost certainly as active in the recent past as Earth's moon was when it was laying down the maria," says Stern. "It's as active as the average value for Earth or Venus."

If Triton is active, then other small worlds in the outer solar system might also be active, including Pluto. This activity could manifest itself as cryovolcanism — volcanism that spews lava made of water-ice instead of molten rock.

So what causes this activity? Perhaps, says Stern, Neptune captured Triton only 1 billion to 2 billion years ago. Triton's orbital evolution following this capture would have frictionally heated the moon, creating a molten ball of magma and water that is still cooling off.

Stern and McKinnon will publish their results in the February 2000 issue of the *Astronomical Journal.* — R. N.

The surface of Neptune's moon Triton appears far younger than previously thought, indicating that the moon may still be active.



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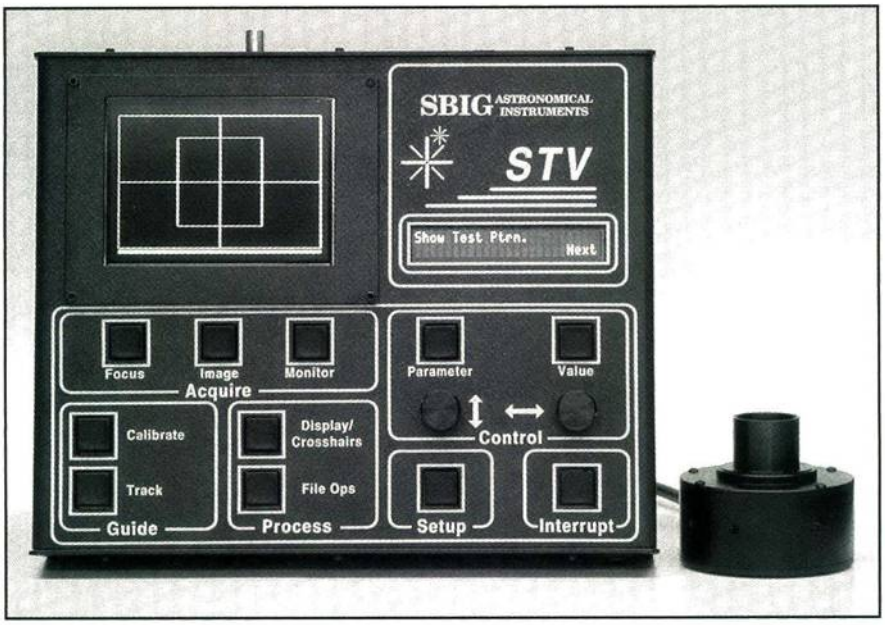
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MOON MYSTERY

Lunar Activity Doesn't Pan Out

The moon frustrates every amateur astronomer who has reported seeing a "lunar transient phenomenon" (LTP), only to have professional astronomers discount each event. Amateurs, convinced they have witnessed the immediate aftereffects of impacts or outgassings, sometimes spot lunar glows, darkenings, or other sights. Professionals attribute LTPs to a variety of possibilities, including atmospheric disturbances or overactive imaginations. When it comes to LTPs, small-scope serendipity is no match for the big-science view that the moon is unchanging and geologically dead.

"Lunar transient phenomena are slightly above UFOs in terms of their credibility with the scientific community," says Bonnie Buratti, an astronomer at the Jet Propulsion Laboratory. However, Buratti was swayed to re-examine images taken in 1994 by the Clementine spacecraft to follow up some amateur observations. To her surprise, a pair of Clementine images seemed to corroborate one amateur's LTP.

A sudden brightening in the Aristarchus region of the moon was reported by one amateur astronomer, but professionals were not able to corroborate it.

S. Calkins/Clementine image

Robert Manske of Waunakee, Wisconsin, was scanning the moon's Aristarchus plateau on April 23, 1994, with an 8-inch telescope when he noticed "an obscuration or darkening" at a collapsed lava tube called the Cobrahead. He was one of about 200 amateurs organized by David Darling with the Association of Lunar and Planetary Observers (ALPO) to systematically observe the moon during spring 1994 when Clementine was photographing it.

In 1999, Sascha Calkins, a graduate student of Buratti's at the California Institute of Technology, sifted through two million Clementine images searching for any that could corroborate four LTPs reported by ALPO. Her initial efforts delighted amateurs. She reported "good quantitative confirmation" of Manske's LTP at the October 1999 meeting of the American Astronomical Society's Division for Planetary Sciences. Clementine images taken before and after Manske's LTP revealed "a measurable difference in color" in the Cobrahead.

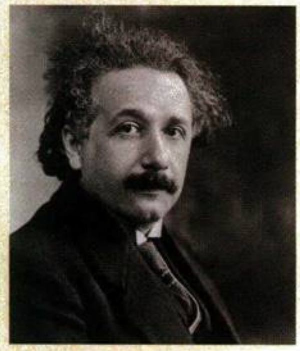
However, Calkins and Buratti later re-evaluated the data more carefully. "We created new calibrations for the Clementine images, and the event isn't there any more," says Buratti. She plans to publish the latest results in *Icarus*.

Amateurs have reported seeing hundreds of LTPs over hundreds of years. They seem to be associated most frequently with about 30 lunar features, including the Cobrahead. Darling, Manske, and other amateurs plan to continue their lunar observations. "Don't quit looking," says Manske.

— Rex Graham

And the Winner Is . . . Albert Einstein

As 1999 drew to a close, it seemed that everyone was promoting a list of the best of this or the greatest of that covering the decade, century, or millennium. While some of those lists bordered on the trivial — and many others gallantly crossed that border — a few helped put the accomplishments or personalities of the given era in perspective. One of the latter came from the British journal *Physics World*, which surveyed 130 leading physicists from around the world to come up with a list of the greatest physicists of all time. And the winners are: #10) Ernest Rutherford, #9) Erwin Schrödinger, #8) Paul Dirac, #7) Richard Feynman, #6) Galileo Galilei, #5) Werner Heisenberg, #4) Niels Bohr, #3) James Clerk Maxwell, #2) Isaac Newton, and #1) Albert Einstein.


Yerkes Observatory

Albert Einstein has been named the greatest physicist of all time.

Bright Nova Lights up Aquila

On December 1, Portuguese amateur astronomer Alfredo Pereira discovered a bright nova in Aquila. Pereira, who made the discovery with a pair of 14x100 binoculars while observing out a window of his house, had logged more than 500 hours searching for novae before finding this one. Within a few days, Nova Aquilae 1999 Number 2 (located 2° north-northwest of Delta Aquilae) had brightened from 6th to 4th magnitude. It soon began fading, however, dropping to 6th magnitude within two weeks. Unfortunately, by the time Aquila re-emerges in the morning sky in late February, it should be down around 10th magnitude. Novae arise in close binary systems containing a white dwarf and a normal star expanding on the way to becoming a red giant. Material from the star flows onto the white dwarf, and when enough has accumulated it undergoes a thermonuclear explosion — the nova outburst.

You Know My Name, Look Up the Number

If the mere mention of Avogadro's number causes unpleasant flashbacks to high school science class, you may want to skip the rest of this story. But if knowing the exact speed of light is your cup of tea, read on. The National Institute of Standards and Technology (NIST) has developed a website that gives the most up-to-date values for the fundamental constants of nature along with the uncertainty of those values. You can access the website at http://physics.nist.gov/constants. And by the way, the speed of light (in a vacuum, of course) is 299,792,458 meters per second.

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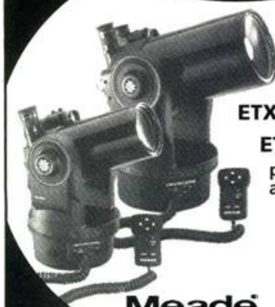

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Celestron Nexstar 5

CELESTRON Counter-punches with its entry into the mid-size computer-driven telescope market. The Celestron **Nexstar 5** combines time-proven Celestron 5" Schmidt-Cassegrain optics, a single metal fork arm and smooth drive system to make an excellent visual and photographic telescope. The built-in computer has 18,473 objects. Celestron's Nexstar 5 is ready out of the box to run from AA batteries or AC current.

The Nextar 5 is a fine value at $1,199.

Other Celestron Telescopes at Lumicon

Ultima 2000	$2699
Celestar Deluxe	$1699
Celestar	$1099
CM 1100– 11" SCT	$3399
Starhopper 8" Dob	$429
Starhopper 6" Dob	$339
C102-HD 4" Refractor	$499
FS114 Deluxe	$299
CR150 6" f/8 Refractor (NEW!)	$1199

Lumicon Eyepiece with Pulseguide Allows Guiding While Using Fainter Stars

The Lumicon Guiding Eyepiece with (Rigel) Pulseguide Illuminator makes a wonderful combination for guiding astrophotos. The eyepiece has dual crosshairs, allowing you to "box in" your guide star. The Pulseguide Illuminator has three adjustments for setting brightness and blinking speeds. Thru the eyepiece you alternately see your guide star against a black background and superimposed with dual crosshairs at whatever speed you choose.

New low price $99.50

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AMAZING O-III FILTER™

"The LUMICON O-III proved to be our favorite . . .it gave the greatest contrast gain."

ASTRONOMY, February 1991

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"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in more than two dozen objects I viewed." *SKY & TELESCOPE, July 1995*

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SKY & TELESCOPE, July 1995

See The Horsehead!

"LUMICON's H-Beta Filter will show subtle features in emission nebulae that others fail to reveal. It can't be beat for the elusive Horsehead and California Nebulae." *SKY & TELESCOPE, July 1995*

Deep-Sky Filter™
BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for both color and black and white photography.

Best Wide-Band Filter!

"Based on our tests, we'd recommend a LUMICON Deep-Sky and Oxygen III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for reflection nebulae."

ASTRONOMY, February 1991

LUMICON Multiple Filter Selector, holds 5 1 1/4" filters .... $129; $99 if ordered w/filter
1 1/4" LUMICON DEEP SKY Filter threads into most 1 1/4" eyepieces $99.50
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Also fits EASY-GUIDERS $199.50
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camera T-threads for prime focus photography $199.50
72mm LUMICON Giant DEEP-SKY Filter
(62, 67, 77mm adapter, $10, 82mm $16) $399.50
2" Rear Cell Filter, fits SCT's............Deep-sky, $199.50 UHC,O-III, H-Beta $199.50
1 1/4" LUMICON UHC Filter threads into most 1 1/4" eyepieces $99.50
48mm LUMICON UHC filter fits most 2" eyepieces $199.50
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501nm O-III lines. ....1 1/4" $99.50 .... 48mm $199.50
Lumicon Comet (Swan Band) FIlter............................1 1/4" $99.50 .... 48mm $199.50
Universal Adapters for 1 1/4" filters. Adapts the filters to any 1 1/4" eyepiece $19.50
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LUMICON Sky Vector Features:

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C-14 add $75.

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5X Powermate boosts magnification 5x	$168
Ranger 70mm f6.8 apchromat w/45° diag.	$685
Pronto 70mmf6.8 w/45° erecting prism	$925
Tele-Vue 85,85mm f/7 APO telescope	$1995
Bino-Vue binocular w/2x correc.	$1030
Gibraltar mount with ash wood tripod	$530
8,11,15mm Plossl . $82 — **20,25mm**	$95
32mm Plossl, widest true field in 1 1/4"	$110
55mm Plossl, widest possible field	$230
2.0x or 3.0x Tele Vue Barlow Lens	$105
2" Giant Barlow – 2x	$168
4.8mm Nagler 82° field, 1 1/4 " eyepiece	$175
7mm Nagler, 1 1/4 " eyepiece, 82° field	$220
9mm Nagler, 82° field 1 1/4 " or 2"	$240
12mm Nagler Type 4, 82° 1 1/4 "or 2"	$340
16mm Nagler Type II, 82° 1 1/4 "or 2"	$310
17mm Nagler Type 4, 82° 2" only	$370
22mm Nagler Type 4, 82° 2" only	$445
31mm Nagler Type 5, 82° 2" only	$595
2" Paracorr visual coma corrector	$235
3,4,6,8,10,14mm Radian,60° field	$228
15mm Panoptic 1 1/4", 68° field	$210
19mm Panoptic 1 1/4", 68° field	$240
22mm Panoptic 1 1/4"/2", 68° field	$280
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Note: TeleVue warranty may not be valid outside USA

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Too many amateur astronomers make a mistake! They purchase the refractor or Schmidt-Cassegrain of their dreams, add a great eyepiece and then join both with a cheap prism star diagonal.

Lumicon Star Diagonals have a 1/8th wave guaranteed mirror surface. Compare that to the 1/4th to 1 wave errors found in standard prism diagonals that come with today's telescopes. Enhanced aluminum coatings ensure bright images.

Perform your own test. At high power, try viewing through your scope with or without your star diagonal. If you can see a difference, you need a Lumicon Star Diagonal.

Special Offer Thru March

Lumicon 1.25" Mirror Star Diagonal	$89.50 (Save $10)
Lumicon 2" Mirror Star Diagonal	$189.50
With 2"/1.25" reducer **FREE** ($25 value)	
Adapter for 2" diagonal to SCT	$29

Meade's New 'Table Top' Scopes

Meade instruments now has two choices in the table top computer controlled scope category. Maksutov optics deliver sharp, high-contrast views in both the 90mm and 125mm sizes. The optional Autostar computer creates an excellent astronmy classroom on a tabletop.

ETX 90	**$595**
ETX 125	**$895**
Autostar (14,487 objects)	**$149.95**

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8"LX10 w/wedge, hand controller ($65)	$995
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8" LX50 w/wedge ($115 P&S)	$1395
Adj. tripod for 8-10" SCT ($30 P&S)	$295
8" LX200 w/computer ($105 P&S)	$2795
Wedge for photographing w/8" LX200	$139
7" LX50 f/15 Maksutov w/wedge ($125 P&S)	$1795
10" LX50 f/10 w/wedge, dec. motor, hand controller ($155 P&S)	$1695
10" LX 200 w/ computer ($155 P&S)	$3195
12" LX 200 (f/10 only) ($215 P&S)	$4495
SuperWedge for photo. w/10", 12" LX200	$395
16" LX200 f/10 w/tripod ($385 P&S)	$14,950

LX50 – includes dec. motor, hand controller.
LX 200 - full computer control w/64k mem.
Tripod: Extra for LX 50; included for LX200

Note: Wedge is not needed for visual observing with the LX 200. Select f/10 or f/6.3 (no extra charge) for LX 200.

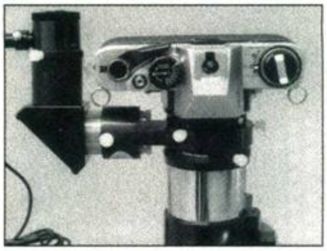
Meade Dobsonians 6 -16"

6"f/8 Dobsonian Starfinder ($46P&S)	$349
6"f/8 Equatorial Starfinder ($79 P&S)	$649
8"f/6 Dobsonian Starfinder ($59P&S)	$449
8"f/6 Equatorial Starfinder ($89 P&S)	$749
10"f/4.5 Dobsonian Starfinder ($85P&S)	$599
10"f/4.5 Equatorial Starfinder ($99 P&S)	$879
12.5"f/4.8 Dobsonian Starfinder ($95P&S)	$895
16"f/4.5 Dobsonian Starfinder (frt. COD)	$1195
16"f/4.5 Equatorial Starfinder (frt. COD)	$2695

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing and shipping charge to the price. Slightly lower P&S for payment by check. Lumicon showroom prices are $50 to $100 higher.

See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.

3 Choices of our Lumicon Easy Guiders ™



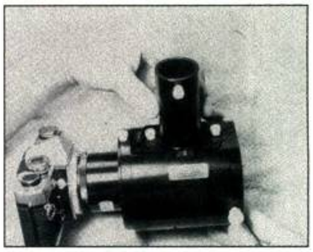
Newtonian Easy-Guider ™

The **LUMICON NEWTONIAN EASY-GUIDER ™** is the best choice on the market for guiding both Newtonian and Refractor telescopes. Off-axis guiding is the surest way to get pin-point star images. The two-way adjustment on the off-axis tube avoids the problems of finding and centering a guide star in your eyepiece or autoguider. A 35mm camera adapter is included (specify camera). Available for either 1.25" or 2" focusers at **$189.50 each**

Cassegrain Easy Guider™

For 8" Schmidtt-Cassegrain telescopes choose the **LUMICON CASSEGRAIN EASY GUIDER™.** Includes mutiple adjustments for easily finding and centering a guide star and for composing the picture. The included internal 50mm focal reducing lens delivers brighter f/6 photographic images and can be used visually with an optional adapter. The lens can be removed for f/10 photography. A 35mm camera adapter (specify camera) is included....**$249**

Visual Adapter **$25**



Lumicon Giant Easy Guider™

The king of off axis guiders is the **LUMICON GIANT EASY GUIDER™.** Made for Schmidtt-Cassegrain telescopes of 10" through 16" diameter, the giant easy guider attaches to the large 3" rear threads of these scopes. Included is an 80mm diameter focal reducing lens capable of delivering f/7 to f/4 photographic speed. Replacing the included 35mm camera adapter (specify camera) with a 2" star diagonal turns the giant easy guider into a full aperture rich-field viewer.......................................**$395**

1¼" viewing adapter for rich-field..**$25**

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28mm F.L., 55° Apparent Field 1¼"	$259
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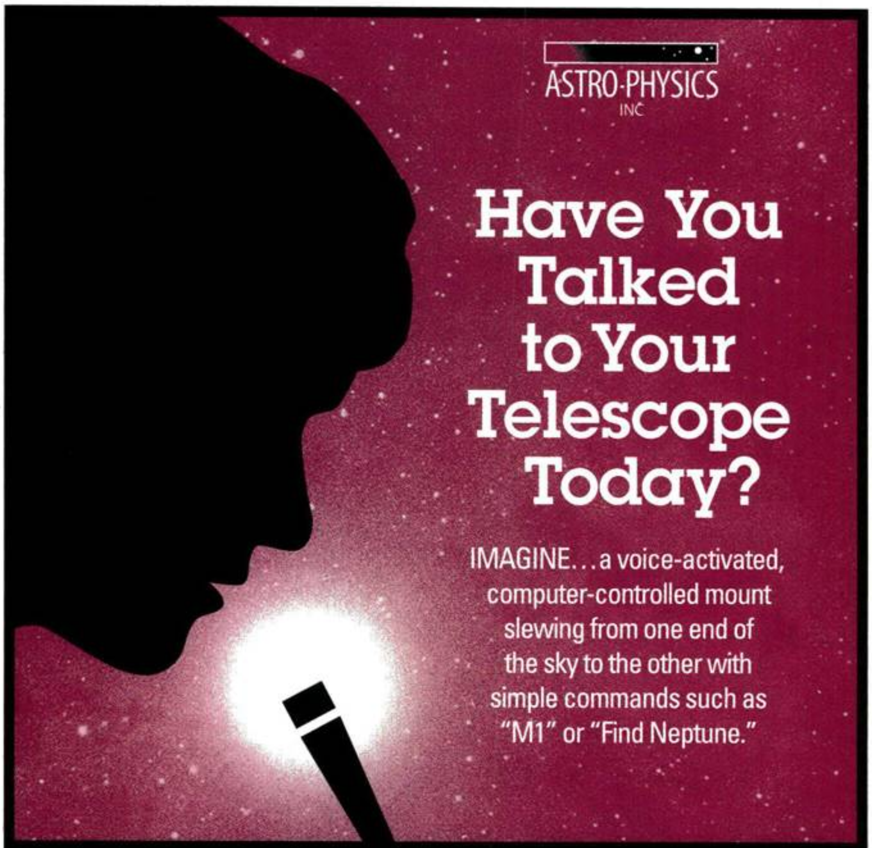

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#497 Autostar **$149**

Hardly a day goes by that we don't get a note or E-mail message like the one reprinted on the next page, or a call that goes something like this: "Your ads are right. So and so on the East Coast advertises low prices – but they don't have what I want in stock, they couldn't answer *any* of my questions, and they wanted my credit card number before they'd even *talk* to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!" One of our customers added, "If I wanted that kind of abuse, I would have called my ex-wife."

If you want the right telescope, you need more than a camera store clerk with a price list, a surly attitude, and a wild guess.

What you *really* need are people who will take the time to listen to what *you* need, people with years of experience using and selling telescopes, people who can help you get the most telescope for your dollar. That's exactly the kind of people you'll find at ***astronomics***.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. We don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

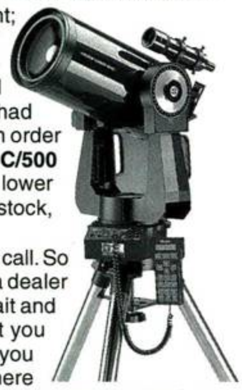
We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs . . . *and your budget* . . . from the many Meade, Celestron, TeleVue, Takahashi, and Questar telescopes we stock at discount prices from $119 to $27,995. (We had 706 telescopes *in stock* as we wrote this on 11/5, and more on order.)

astronomics. No hard sell. No guesswork. Just honest advice, the *right* scope, and a good price. Call us at (405) 364-0858 and find out for yourself.

We order Meade telescopes and accessories by the ton . . . literally!

Meade 203SC $895

The day before this copy was written, we received 305 cartons from Meade – *3¼ tons* of scopes and accessories in one shipment. We don't know of many other dealers – if any – who regularly receive, or actually stock, Meade products in those quantities . . . *no matter what they claim.* But we do. Meade telescopes, binoculars, eyepieces, filters, Magellan computers, Barlows, off-axis guiders, illuminated reticle eyepieces, counterweights, T-adapters, tele-extenders – we keep them all in stock.



Meade 7" LX200 **$3295**

It doesn't matter whether the right telescope for you is one of the computerized 8" or 10" **LX200 Schmidt-Cassegrains**; the **LX200 Maksutov-Cassegrain** 7" to the right; or any of the 8" or 10" **LX50** SCTs. It doesn't matter if it's the 3.5" **ETX-90EC** or 5" **ETX-125EC** Maksutovs with optional go-to computer shown at the top of this page (we had 24 of the 90mm in stock and 600 of the 125mm on order as this was written). It doesn't matter if it's the **203SC/500** German mount 8" SCT, shown above left at its new lower price. If Meade is shipping it for a dealer to keep in stock, the chances are good that we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade telescope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***

We buy Celestron by the ton, too!

The week this was written, we received 9791 pounds of Celestron scopes and accessories in a single shipment – 21 pallets, a full trailer load. The week before, we got a separate 3950 pound shipment from Celestron. We have hundreds of Celestron scopes in stock for immediate shipment, plus accessories galore. We don't know of many other dealers – if any – who order and stock Celestron in those quantities. But we do.

Because we buy in large quantities, we can take advantage of special buys. And we pass those extra savings on to you.

We stock Pentax eyepieces.

From 5.2mm to 40mm, we stock all the Pentax wide field (55°-65°) long eye relief (20mm) ultra-premium ED glass eyepieces . . . all at *very* unpremium prices.

We stock Celestron's new NexStar 5 go-to computerized scope!

Celestron 5" NexStar 5 **$1199**

The 5" Celestron **NexStar 5** computerized scope puts sharp and bright f/10 Schmidt-Cassegrain optics into a sleek metal housing that brings go-to telescopes into the new millennium in style!

NexStar hand control

The scope's *standard equipment* computer hand control stores snugly in a recess in the rigid single metal fork arm (and can be operated while stored there, as well as when it's undocked and hand-held at the end of its coiled cord). The computer quietly moves the AA-battery powered NexStar to 18,473 stars and objects at a fast 6.5° per second. It also takes you on guided tours of the most spectacular deep sky objects that are visible on the night you are observing. An AC adapter is standard, not a costly option. Also standard are electric slow motion controls; a 26mm Plössl eyepiece with a field of view that's more than twice as wide as the full Moon; and a non-magnifying Star Pointer red dot finder that's ideal for eyeglass wearers.

Celestron's 5" true-multicoated optics have been used on the Space Shuttle. If they're good enough for NASA, imagine what they can show you. Then imagine what the **NexStar 5** can *find* for you – *automatically!* But you don't have to imagine it. You can experience it for yourself . . . only a few short days after you order a **NexStar 5** from ***astronomics!***

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Celestron C8 Special Edition
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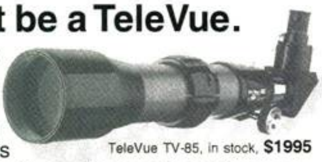
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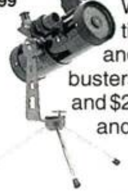
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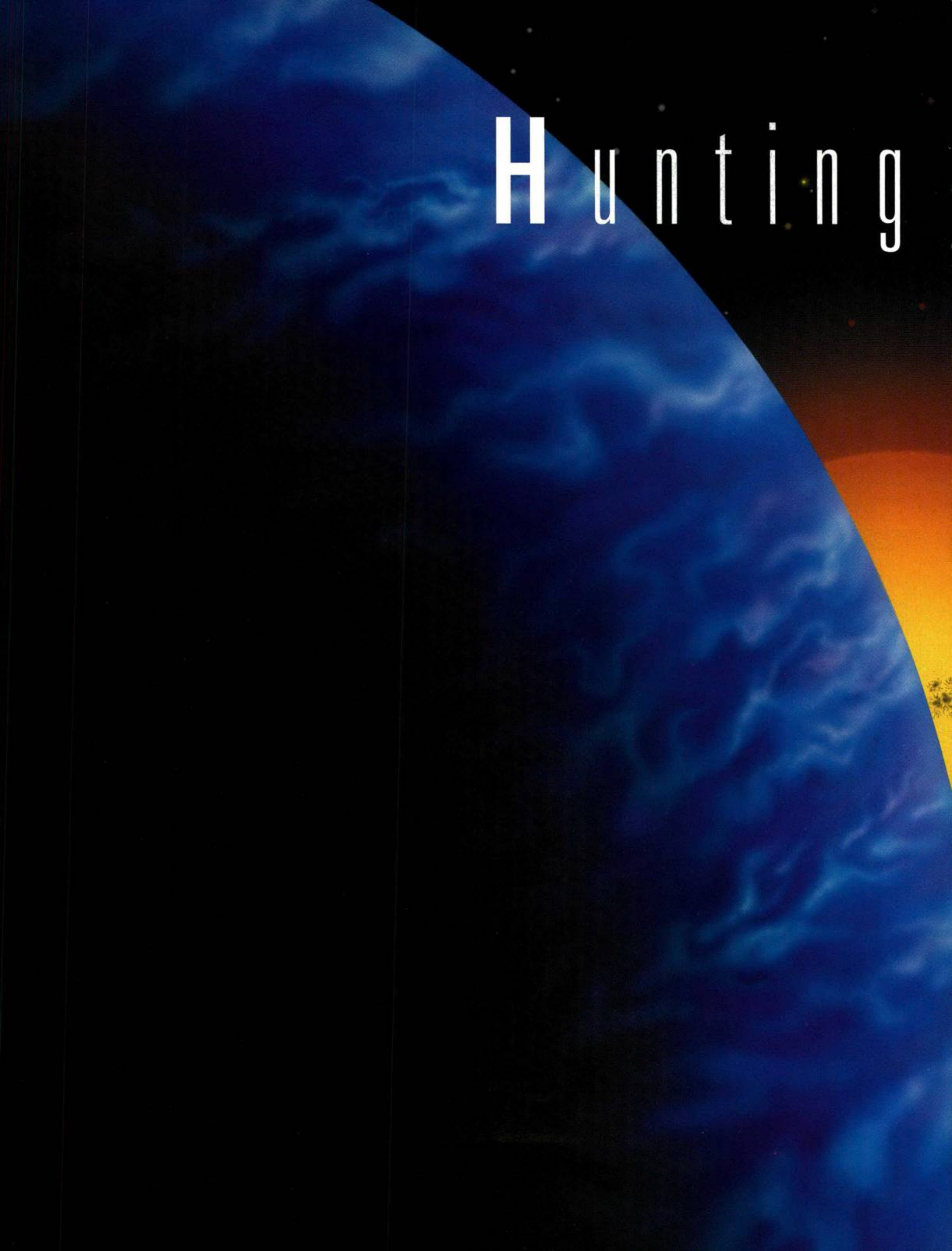


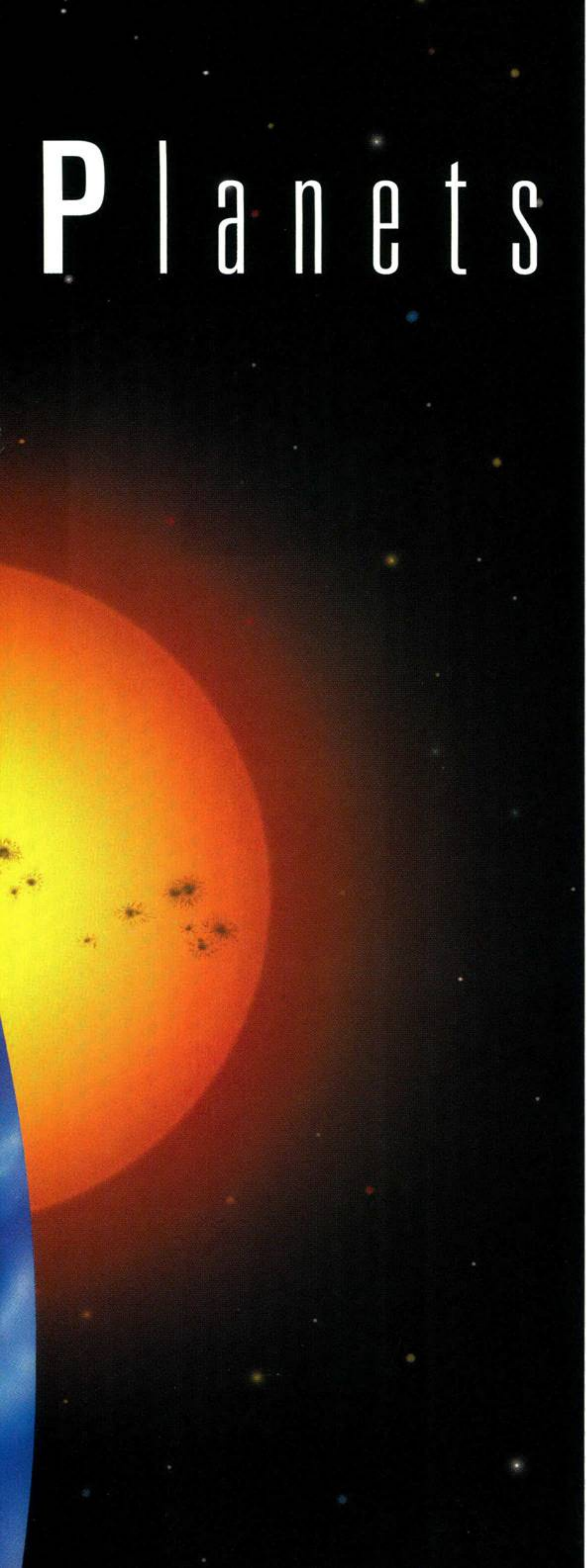
Planets Beyond

Ten years ago there were none, now there are 33. Extrasolar planets are telling astronomers how planetary systems form and evolve.

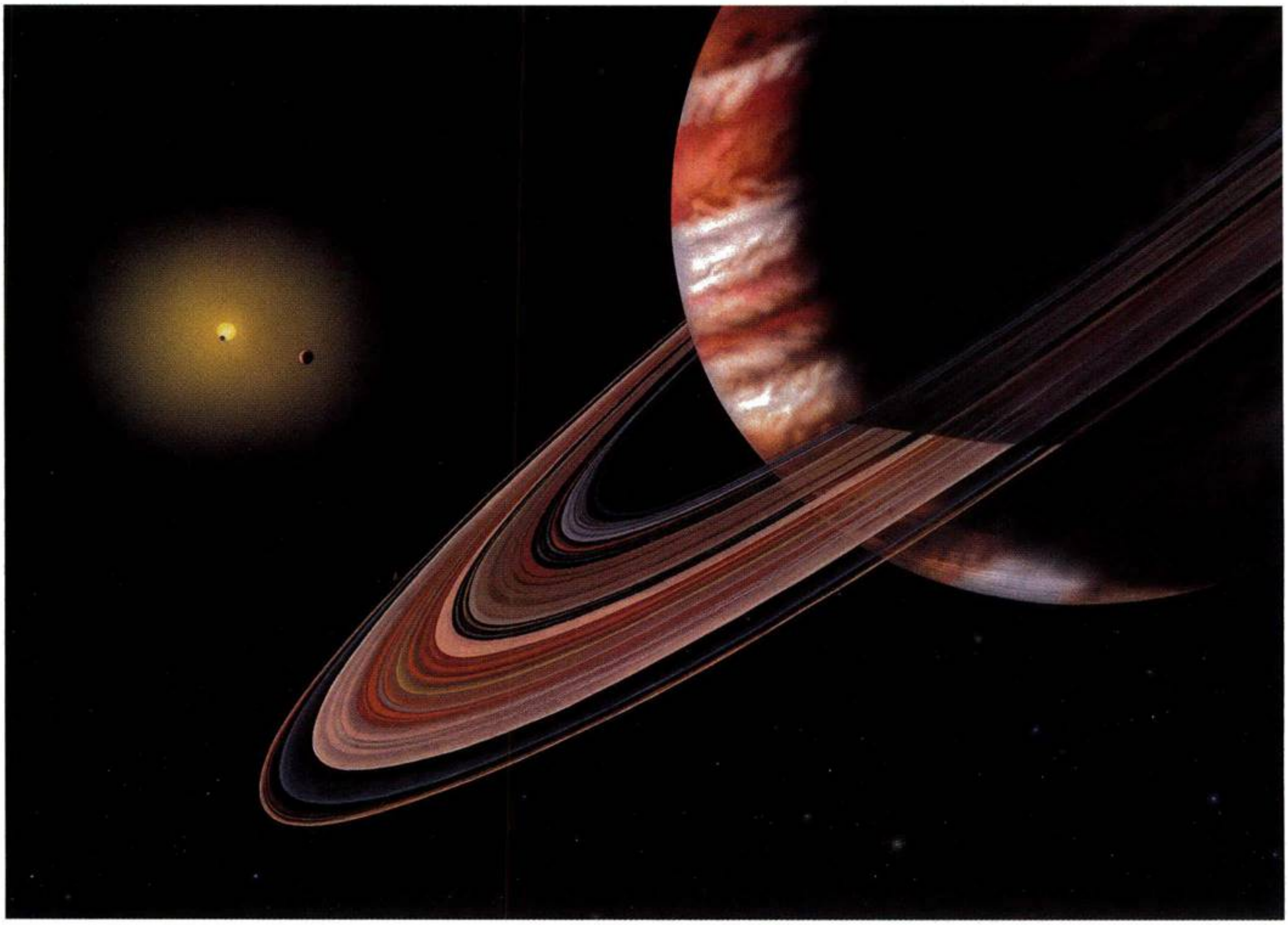
Text by Geoff Marcy and Paul Butler
Paintings by Lynette Cook

THE MOST REMARKABLE TOOL ASTRONOMERS USE might not be a telescope nor a computer, but the human imagination. With it, we unconsciously yearn to stitch together a quilt of cosmic knowledge based on patchy research in astronomy, physics, chemistry, and biology. We want to learn how our brief lives are intertwined with the planets, stars, nebulae, and galaxies.

During the past year, our team and others have discovered a dozen or so planets orbiting other stars. Our team alone recently added five new planets to the list. These discoveries highlight a key element in our connection to the universe. The 33 extrasolar planets now known clearly tell us that the Milky Way Galaxy's 200 billion stars must harbor billions or possibly trillions of planets.



A 1.3-Jupiter-mass planet orbits HD 217107 at only 0.07 AU.



The first true planetary system around a solar-type star was found around Upsilon Andromedae. The star has at least three planets.

Surely there must be many lukewarm worlds that can host complex organic chemistry, leading to replicating molecules that compete with one another for energy and resources. The seeds of life are sewn in such environments, and there is no reason to doubt that increased biological complexity follows naturally.

But we're interested in more than just life. We'd like to know how planetary systems form and evolve. Despite our successes, our planet search is still in its infancy. Still, with 33 planets already in hand, we see a few general trends. Planet formation appears to be a chaotic process that often tosses Earth-size planets out of their systems entirely, leaving Jupiter-mass brutes behind in highly elongated (eccentric) orbits. Failed stars called brown dwarfs appear to be infrequent companions to solar-type stars. We have found the first full-fledged system of planets around a sunlike star, and other stars also show signs of multiple Jupiters. Looming on the horizon are techniques to find Earthlike planets, a quest bound to raise more puzzles for astronomy and biology.

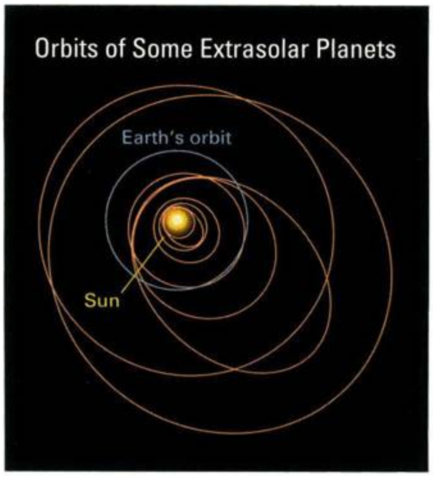
Parade of Planets

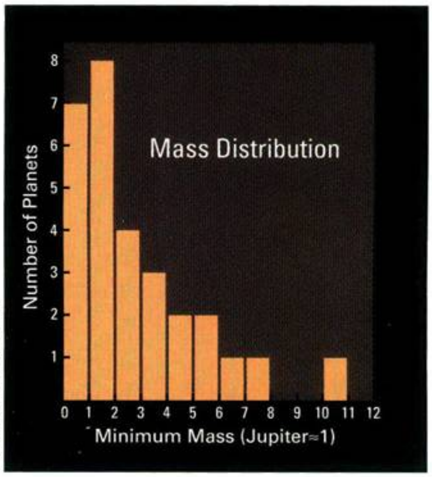
The parade of extrasolar planets around normal stars began in 1995 when Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland discovered a planet at a distance of only 4.6 million miles, or 0.05 astronomical unit (AU), from the star 51 Pegasi (one AU is the average Earth-sun distance). This was followed shortly thereafter by our discovery of planets around 47 Ursae Majoris and 70 Virginis. The star-hugging orbit of the 51 Pegasi planet and the eccentric orbit of the 70 Virginis planet shook our myopic, heliocentric expectation that planetary systems would be nearly identical to ours. Instead, planets fill orbital niches of unimagined diversity.

We don't have the technology yet to image these planets; they're swamped by the glare of their host stars. Instead, we find planets by looking at how they yank their stars as the they go around in their orbits. The jerky motion of a star is revealed in the star's spectrum. As the star approaches Earth in response to the planet's gravity, its light is shifted toward the blue end of the spectrum. As the star recedes, its light is shifted toward the red. This subtle Doppler signature woven into the light of the parent star allows us to reconstruct the orbit and minimum mass of an otherwise hidden planet.

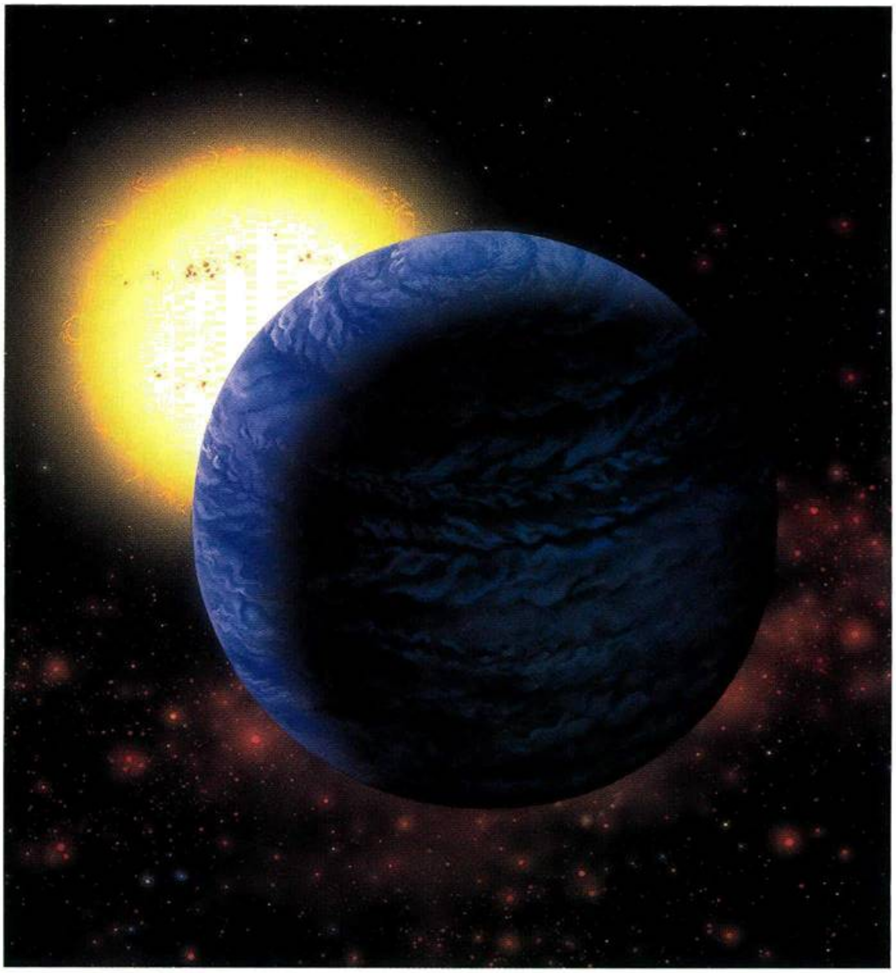
The nearly circular orbits of the planets in our solar system led astronomers to expect that planets around other stars would reside in circular orbits too. After all, planets probably form in circular protoplanetary disks, such as the disks seen in the Orion Nebula. The gas and dust in these disks follow circular orbits, and friction within these disks would circularize the orbits of newly forming planets in much the same way that friction circularizes the flow of water going down a bathtub drain.

But most of the extrasolar planets found so far reside in highly eccentric orbits, not circular. Indeed, the 18 extrasolar planets with the largest orbits all reside in eccentric orbits.





Astronomy: Elisabeth Rowan



Upper left: Almost all the extrasolar planets discovered to date have highly elongated (eccentric) orbits. Lower left: A histogram shows that most of the planets found so far have masses of less than two Jupiters, even though more massive planets are easier to detect. Above: A 3.4-Jupiter-mass planet orbits the sunlike star HD 195019.

Most of those orbits are more than twice as elongated as the orbits of Earth, Jupiter, or Saturn.

Why are other planetary systems dominated by elliptical orbits rather than circular? The best clue comes from comets in our own solar system. Comets reside in orbits so elongated that they visit the inner solar system only rarely. But comets did not form in elliptical orbits. Rather, they formed in circular orbits in the protosolar disk. Comets were gravitationally flung into their present-day elliptical orbits when they ventured too close to planets, in much the same way spacecraft receive gravitational assists from planets.

We now suspect that most planets themselves engage in this slingshot activity, leaving them in disturbed, elliptical orbits. If two or more massive planets form in orbits a few AU apart, this fate is inevitable. One planet will be scattered inward, the other outward. If even one planet suffers this slingshot effect, it will likely travel close enough to neighboring planets to disturb them as well. This theory explains why the large majority of the extrasolar planets found to date reside in noncircular orbits.

Unfortunately, Jupiter-mass planets toss Earth-mass planets around like Tinkertoys in a train wreck. The resulting chaos may result in some planets being gravitationally ejected from the planetary system altogether, leaving only the most massive survivors behind. Our Galaxy must be filled with trillions of Earth-size rogue planets — dark, rocky hulks wandering aimlessly through interstellar space.

The predominance of elliptical orbits implies that planetary systems with circular orbits may be the exception rather than the norm. Apparently, our nine planets were just far enough apart and low enough in mass to avoid this chaos. The nine planets do perturb one another, but not enough to cause close passages. The planetary house of cards that we call our solar system may be one of the rare systems that remains just barely stable (see "Crack in the Clockwork," May 1998).

If our solar system is unusual in its circular orbits, we humans would seem to be extraordinarily lucky to be here. After all, the circular orbit of Earth keeps solar heating nearly constant, minimizing temperature fluctuations. Perhaps biological evolution would not have proceeded to intelligence if Earth's temperature were fluctuating wildly. It may be that Darwinian evolution toward complex organisms is enhanced by relatively quiescent climates enabled by circular orbits. If so, we owe our existence to Earth's stable orbit.

Triumph of the Small

Ultimately we would like to directly "see" these planets and take their spectra. But until technology catches up with our dreams, there is still much information to be gleaned from a statistical analysis of our current harvest of planets.

We use a "mass histogram" to categorize the planets that have been discovered. We create a mass histogram by putting each planet in a "bin" according to its mass. The number of planets in each mass-bin indicates whether higher- or lower-mass planets are more common. The 29 extrasolar planets in the mass histogram on page 45 represent all the planets found around normal stars (the other four planets orbit pulsars). Four groups in the United States and Europe have made these discoveries: our team, the Swiss team led by Michel Mayor, a team led by Robert Noyes of the Smithsonian Astrophysical Observatory and Tim Brown of the National Center for Atmospheric Research, and a team led by Bill Cochran and Artie Hatzes of the University of Texas at Austin and Martin Kürster of the European Southern Observatory.

All the surveys are primarily sensitive to Jupiter-mass planets with orbital periods of three years or less. Massive companions are the easiest to detect because they tug harder on their host stars. Our surveys can find virtually all stellar companions with three or more Jupiter-masses and orbital periods of three years or less. But we could easily overlook planets of one Jupiter-mass or less, and we can't detect Neptune-mass planets. This selection effect strongly favors the discovery of planets with five Jupiter-masses or more relative to those of one Jupiter-mass. But the mass histogram clearly shows that we are finding more of the lower-mass planets. This implies that the planets discovered to date represent just the tip of the planetary iceberg and that as our techniques improve, we will find many more lower-mass planets.

Remarkably, all the companions found by our team's velocity survey are less than 10 Jupiter-masses. When our Lick Observatory planet search around 107 sunlike stars began in 1987, we expected to find both planets and brown dwarfs. Brown dwarfs are failed stars of 10 to 80 Jupiter-masses (see "The Little Stars that Couldn't," August 1999). Because brown dwarfs have higher masses than planets, brown dwarfs are much easier to detect. But during the past 12 years of our Lick survey, we haven't found a single brown dwarf companion around any of our 107 stars. This proves that only about one in 200 solar-type stars have brown dwarf companions within five AU.

Multiple Planets

The solar system's rich diversity of planets displays an astonishing range of environments, from pancake-shaped volcanic domes on Venus to the frozen rings of Saturn. But to an impartial observer, the solar system essentially consists of the sun, Jupiter, and some leftover debris. If alien astronomers are looking at the solar system with technologies similar to our own, they will only detect the sun, Jupiter, and maybe Saturn. We therefore shouldn't be surprised that the first rush of discoveries involved single planets.

The discovery of multiple-planet systems requires a combination of precision, patience, and luck. Reliable detection of an extrasolar planet by our Doppler technique requires that observations span a time covering at least two orbits. Because our survey is only 12 years old, we haven't been searching long enough to detect planets with orbital periods longer than six years. We have only been searching long enough to detect those systems with multiple Jupiter-mass planets orbiting within 4.5 AU of their parent stars.

Still, last year our team and Robert Noyes's team codiscovered the first true extrasolar planetary system, around the solar-type star Upsilon Andromedae just 44 light-years away. Three planets orbit the star at distances of 0.06, 0.82, and 2.4 AU respectively. Our team originally discovered the innermost planet in June 1996 as part of our Lick survey. This planet has a scorching hot 4.6-day orbit and a minimum mass of 0.7 Jupiter. Like the four other 51 Pegasi-like planets with orbital periods of less than five days, the orbit is circular because of tidal interactions with the parent star.

Transit Planet

Geoff Marcy and Paul Butler's team find extrasolar planets by observing how the gravity of a planet tugs upon its parent star. By late 1999, 28 planets had been discovered around normal stars by this indirect method. But because these planets had not been imaged or detected by other direct methods, a small but vocal minority of astronomers questioned whether these planets actually existed.

In November 1999, two teams of astronomers silenced the skeptics with a discovery that vindicates this method of indirect planet detection. One team was led by David Latham and Robert Noyes of Harvard. The other was Marcy and Butler's group.

Both teams detected the gravitational signature of a 0.63-Jupiter-mass planet orbiting the solar-type star HD 209458 at a distance of 0.045 AU. Both teams realized that the planet was so close to its star that there was a 10 percent chance that it would periodically cross the disk of the star, an event known as a transit.

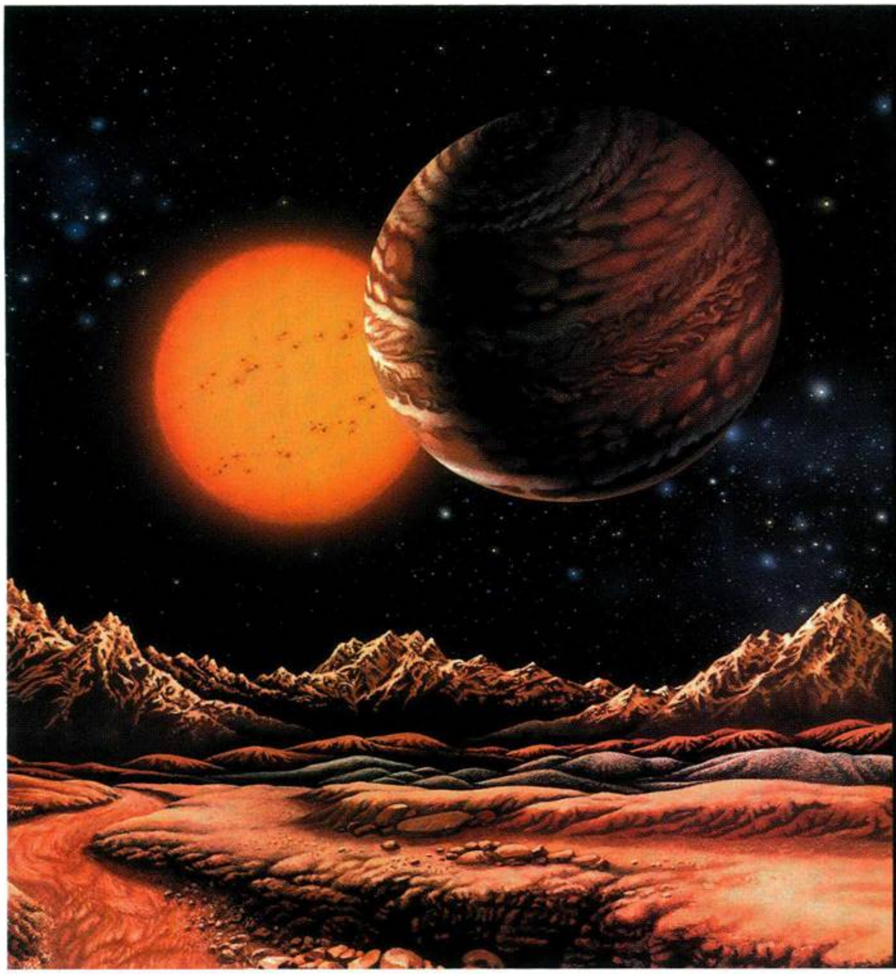
Sure enough, follow-up observations by Dave Charbonneau of Harvard and Tim Brown of the National Center for Atmospheric Research, Greg Henry of Tennessee State University, and others, detected transits at exactly the times predicted. These observations prove beyond a shadow of a doubt that the planet is real (it also suggests that most or all the planets detected by indirect means are real). Moreover, by seeing how much of the star's light was blocked, Charbonneau and Brown were able to calculate the size of the planet: It's 30 percent larger than Jupiter. The planet must be a gaseous world puffed out by the heat of its star. — *Robert Naeye*

Because our data indicated that there were more planets in the system, our group and Noyes's group independently monitored Upsilon Andromedae as often as possible. By early 1999, the two groups had collected more than 140 observations. This enabled us to untangle the complicated pattern of additional velocities, which revealed not one but two additional planets. The middle planet is a 2-Jupiter-mass planet in a 241-day eccentric orbit, while the outermost planet is a 4-Jupiter-mass planet in a 3.5-year eccentric orbit.

With the possible exception of the companion to 47 Ursae Majoris, all the extrasolar planets found to date are either "51 Peg-like" or eccentric. In the Upsilon Andromedae system we have both types of planets, perhaps making this a Rosetta stone that will allow us to understand the formation and evolution of these alien planetary systems. At present we have virtually no idea how the Upsilon Andromedae system formed with its current architecture. As our planet searches improve their precision, time baseline, and sample size, we will find many more multiple planet systems.

A Promising Future

Before 1995, our *primary* goal was simply to find an extrasolar planet. Now, with 33 planets known, we're pushing the goal posts back. We want to find solar system analogs,



A 2-Jupiter-mass planet orbits the red dwarf Gliese 876.

In this April sky, stars are perched, some long
dead, irrelevant light that only now reaches us,
on this, a night so clear I look up from the road,
imagine my car a ship guided by Andromeda,
as if I could let go the wheel, glance up into the
lit distance, know in my bones I will reach home,
the starlight a hand staying all my fears.
The velocity of planets whirling above our heads;
questions of life beyond our own fade as my astral
thoughts regard a woman, closer than the stars,
head thrown back perhaps, eyes closed tight - her
departed child lost in the high and ominous light.

- Herman Beavers, University of Pennsylvania, 1999

marked by Jupiter-mass planets in distant (5 AU) circular orbits. We also want to find Saturn- and Neptune-mass planets, and ultimately, Earth-mass planets. We want to broadly understand the formation and evolution of planetary systems. We also want to know if our solar system is a common type of planetary system or some quirk of star formation (implying that advanced life might be rare in the Galaxy).

To answer these questions we will need to extend our current surveys and develop new technologies. Over the next 10 years our tried-and-true Doppler technique will continue to provide the bulk of extrasolar planet discoveries. Within the last three years both the Swiss group and our group have expanded our surveys to about 1,000 stars, with telescopes covering both the northern and southern hemispheres. By 2010 these surveys will provide the first hints about the fraction of planetary systems similar to the solar system, with giant planets orbiting out to 5 AU and beyond.

Over the next decade, optical and near-infrared interferometry will finally become a reality, with systems operating at the twin 10-meter Keck Telescopes and the European Southern Observatory's Very Large Telescope (VLT). By combining beams of light from several 8- to 10-meter telescopes, these interferometers will be able to measure the position of stars 10 to 100 times more precisely than the current state-of-the-art techniques. This level of precision is required to detect the wobble in a star's position induced by an orbiting Saturn- or Neptune-mass planet.

Making interferometric observations above the blurring effect of Earth's atmosphere should allow even more precise measurements. NASA will launch SIM (Space Interferometry Mission) between 2006 and 2008. SIM will be a five-year mission capable of detecting planets as small as 10 Earth-masses with orbital periods of five years or less.

Advancing technology will eventually put our Doppler method out of business. But our velocity surveys will point the way to missions such as NASA's proposed Terrestrial Planet Finder, which will directly image both Jupiter-size and Earth-size extrasolar planets and look for the spectral signature of life (see "Looking for Life," December 1999). The time is not far off when we can replace the artists' conceptions of extrasolar planets with photographs of the planets themselves and gaze upon landscapes as bizarre and unexpected as those on our nine planets. ◼

Geoff Marcy is an astronomer at the University of California at Berkeley and San Francisco State University. Paul Butler is an astronomer at the Carnegie Institution in Washington, D.C. Marcy and Butler lead a team that has discovered or codiscovered 19 extrasolar planets, more than any other group.

To see a table of all 33 known extrasolar planets, visit *Astronomy*'s website at www.astronomy.com.

Switched at BIRTH

Astronomers are debating how Jupiter-sized planets come to be.

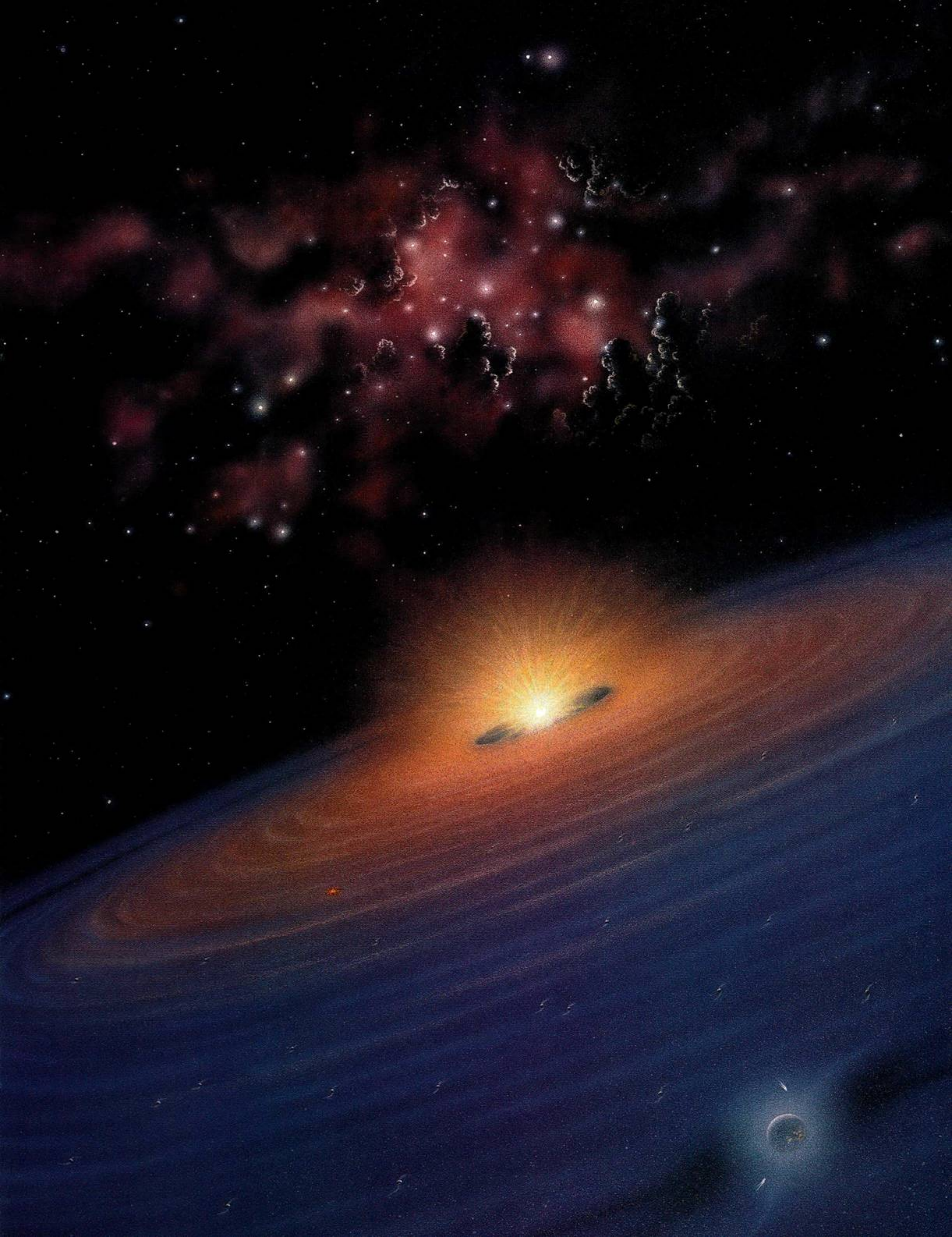
by Mark Sincell

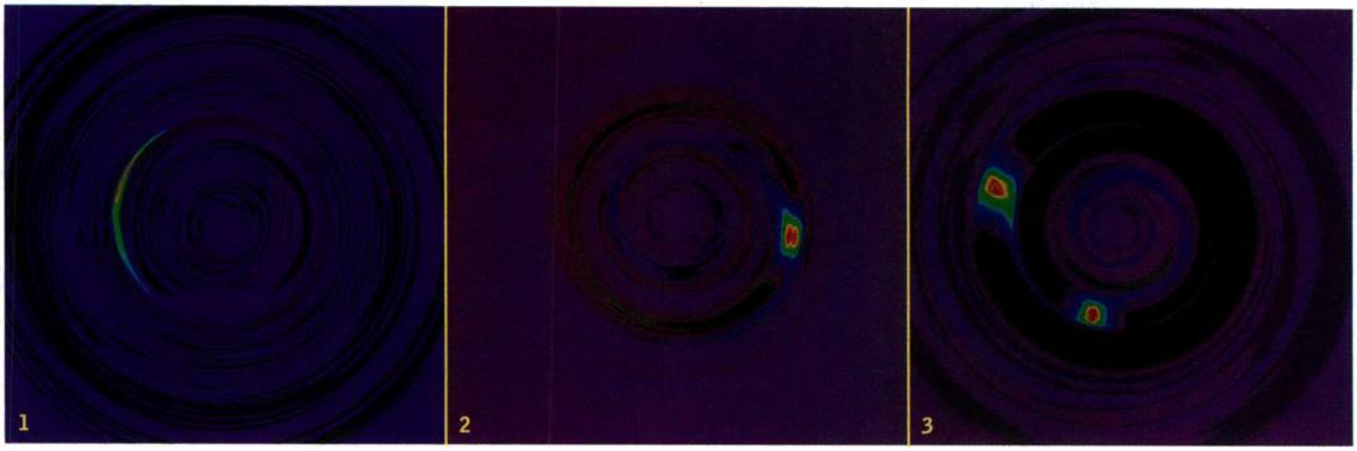
ASTRONOMERS ONCE THOUGHT THAT GAS-GIANT PLANETS FORMED slowly and peacefully. Gravity slowly pulled together debris from the pancake-shaped nebula surrounding a newborn star to form rocky cores several times the mass of Earth. The largest planetary cores swept up vast amounts of the nearby gas, eventually becoming colorful giants. Astronomers thought roughly 1 billion years was needed to make a Jupiter-sized planet by this incremental, core-accretion process.

That view is changing.

Recent computer modeling and discoveries of extrasolar planets suggest that the gas giants we see today are the lucky survivors of a much faster process (see "Hunting Planets Beyond," p. 42). Studies of distant young star clusters suggest that would-be Jupiters and Saturns have only a few million years to grab all the gas they can before most leftover material is ejected from the nascent solar system. Survival is not guaranteed. Once they form, many young, Jupiterlike planets either bounce out of their solar systems or plunge into their parent suns

Lynette Cook





This simulation by Alan Boss shows a disk containing about 10 percent of the mass of the sun forming spiral arms by 2,200 years (1). After 3,000 years (2), two clumps form and merge at 8 astronomical units. (The sun-Jupiter distance is 5 AU.) By 3,500 years (3), the first planet, now at 10 AU, triggers formation of a second planet at 7 AU.

because of complex gravitational interactions with one another and vanish. A startling shift in astronomers' thinking began when Lawrence Livermore National Laboratory physicist Bill Nellis first fired a laser beam at a disk of liquid hydrogen the size of a quarter.

Nellis's laser crunch created metallic hydrogen — a peculiar state in which protons and electrons move freely and conduct electricity. Astronomers believe it fills the cores of giant planets such as Jupiter and Saturn. When Nellis's results were incorporated into computer models of Jupiter, something unexpected appeared. "The models are consistent with a [rocky] core mass of zero," says Lunar and Planetary Laboratory scientist Bill Hubbard. And if Jupiter has no rocky core, or a very small one, core accretion has a more difficult time explaining how it gathered up surrounding gas.

So how did Jupiter form? Carnegie Institution of Washington astrophysicist Alan Boss suggests an alternate to core accretion. He thinks Jupiter may have arisen when a clump of gas in the solar nebula collapsed under its own weight, similar to the way stars form. "I'm the heretic who nobody wants to meet at the party: I'm trying to upset the apple cart," says Boss. "Ten years ago, it was absolutely unanimous that core-accretion was the way to go. Now, it's a horse race with disk instability." His disk-instability model actually is an updated version of a 29-year-old theory.

CONFLICTING MODELS

Proposed by Gerard Kuiper in 1951 and refined by Al Cameron in the 1970s, the disk-instability model says that nebular gas in a nearly uniform protoplanetary disk will abruptly become unstable and contract. Gravity rapidly compresses these clumps into spheres resembling the giant planets Jupiter and Saturn. However, 1970s measurements of Jupiter's gravitational field by the Pioneer 10 and 11 probes suggested that Jupiter contained a rocky core weighing between 10 and 20 Earth masses, which was buried under 300 Earth masses of gas.

"The disk-instability model fell into complete disrepute," says Boss. No one could reconcile a large, rocky core with a collapsing clump of hydrogen and helium gases. Core accretion usurped disk instability.

Proposed in the 1960s by Soviet astrophysicist Viktor Safronov, the core accretion model says that the cores of planets form through the slow agglomeration of tiny pieces of rock floating in the solar nebula. Kyoto University astrophysicist Hiroshi Mizumo completed a series of computer models in the 1970s that showed that once the rocky core reached a critical size of about 15 Earth masses, the rate at which it swept up gas increased dramatically. The striking similarity between the measured and computed masses of Jupiter's core compelled astronomers to embraced the model. After all, it fit with the observed cores of the giant planets and it seemed to take about the right amount of time.

Few new scientific theories remain unchallenged for long, and core accretion faced a major test in the mid-1980s. Astronomers discovered that many stars in young star clusters shone more brightly in infrared light than expected. "An infrared excess is a clear signature of a disk," says National Optical Astronomy Observatory astronomer Steve Strom. Strom and others found that young stars lose their disks after only a few million years. Is a few million years enough time to form the giant planets?

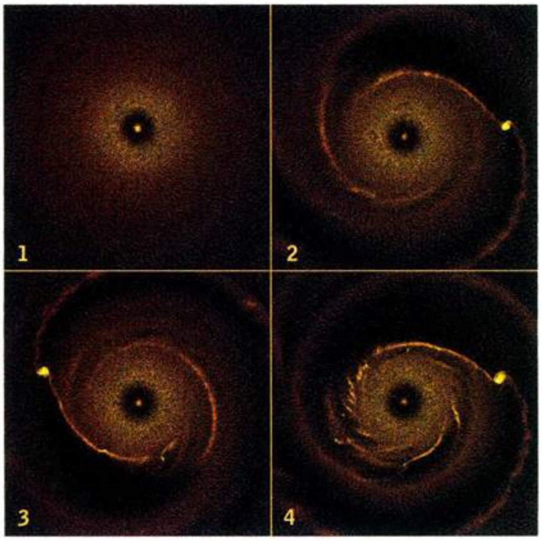
The answer was far from obvious. In its simplest form, core-accretion could take as long as a billion years to form a Jupiter-sized planet. To resolve the question, Jack Lissauer of NASA's Ames Research Center looked more closely at the models. He noticed something that other researchers had overlooked: if all planet cores built up at the same rate, interplanetary competition for the nebular gas would slow the growth of each. "But if one planet gets ahead of the others," explains Lissauer, "its gravity allows it to accumulate solid planetesimals much faster than the others." The process, called runaway accretion, shortened estimated planet-formation times to just a few million years. The core-accretion status quo prevailed, but two new challenges loomed.

PLANETARY DRIFT

Astronomers found the first planets outside the solar system in the 1990s. The model that seemed to fit our solar system couldn't explain the hot, extrasolar planets one-half to ten times the mass of Jupiter that orbit tightly around their parent stars. Most theorists now believe these planets form in the cold realms of solar nebulae, migrate inward, and get hot. In fact, new models of solar system dynamics suggest that migration is common in newly formed planetary systems. Any other planets, debris, and gas in the disk gravitationally push new planets into new orbits. In some cases, these effects could be dramatic. "The gravitational kicks could cause it to spiral into the star in a million years," says Carnegie Institute astrophysicist George Wetherill.

"This raises a question," says Princeton University astrophysicist Scott Tremaine. "Why didn't Jupiter spiral into the sun and take Earth with it?" If Jupiter formed by the slow accretion of gas, the tiny gravitational tugs of other objects could have slowly dragged Jupiter into progressively smaller and, therefore, faster orbits. Although ample evidence exists that Neptune drifted outward significantly over its lifetime, most astronomers agree that Jupiter stayed put.

One possible explanation why Jupiter didn't move is that it formed too rapidly to be decelerated by the nebular gas. In addition, it may not have a rocky core after all — or at least not a significant one. The uncertainty arises because astronomers can't directly measure the mass of Jupiter's core. A small size of jovian core and the complex rotation patterns of the planet's atmosphere make isolating the gravitational effects of its core difficult. "And even if you knew the characteristics of the gravitational field of Jupiter to infinite precision, you wouldn't be able to answer the question," says California Institute of Technology planetary scientist Dave Stevenson. So theorists rely on computer simulations of the jovian interior.



This simulation by Philip Armitage and Brad Hansen represents the evolution of a protoplanetary disk with no planets (1), and one with a Jupiter-sized planet (2). With a planet present, the disk rapidly becomes unstable, fragments (3), and undergoes rapid destruction (4).

Until a few years ago, it was impossible to recreate Jupiter's core conditions in a laboratory. But now, by firing a light-gas gun that compresses a sample of liquid hydrogen by imploding it with laser beams, Nellis's team can create metallic hydrogen that lasts briefly — as long as 100 nanoseconds. With so little time to make measurements, Nellis's team can only estimate the true equation of state in the jovian core. But it is better than nothing.

By comparing their calculations of Jupiter's internal structure to the Galileo probe's measurement of the planet's atmospheric chemical composition and gravitational field, Hubbard and his collaborators were able to refine their estimates of Jupiter's core mass. Allowing for the uncertainty in Nellis's measurement of the hydrogen equation of state, they find that the core mass must be less than 10 Earth masses and could indeed be consistent with no rocky core. "I'm not sure I believe that the core mass is really zero," says Hubbard. "My best guess is between five and 10 Earth masses." But even 10 Earth masses may not be enough to trigger core accretion.

Could Jupiter have consumed 300 Earth masses of gas if it started as a rocky core weighing less than 10 Earth masses? How did it grow fast enough to avoid being consumed by the sun? To answer both questions, Boss resurrects his favorite model. "If you want to make overweight planets," he says, "disk instability is the way to do it." The disk-instability model certainly allows for the rapid formation of planets. "Disk instabilities only take a few thousand years to form a planet around a young star," says Boss. Once a Jupiter-sized planet forms, its larger gravity rapidly pushes the nearby gas out of the way, leaving a stable, clear orbital pathway.

NO CLEAR WINNER

Adam Burrows, an astrophysicist at the University of Arizona, is not ready to abandon core accretion. "The core mass of Jupiter might be too small to initiate core accretion," he concedes, "but the inferred core masses have big error bars, and the upper end is still adequate for core accretion."

Philip Armitage of the Canadian Institute for Theoretical Astrophysics and Brad Hansen, a Princeton University astronomer, reported in *Nature* that the size of a newborn star's protoplanetary disk governs the formation of gas-giant planets. Jupiter-sized planets would grow slowly — over about 10 million years — if the disk is relatively lightweight. "The result could look something like our own solar system," says Armitage. "For a heavyweight disk, more violent processes can occur more quickly and lead to a very different-looking system of planets."

Such findings have prompted many astronomers to suggest that core accretion might not rule out disk instability. "It is important to remember that the two theories are not mutually exclusive," says Southwest Research Institute astronomer S. Alan Stern. "My guess is that both happen and that the issue is which one dominates under which circumstances." University of Hawaii astronomer Tobias Owen notes that the opposite could also be true. "The extrasolar planets could be a warning that we have been too smug," says Owen. "It could be that we really don't understand something fundamental about planet formation." The one thing everyone agrees on is the need for more data. Boss proposes surveying clusters of young stars to determine which ones are wobbling under the pull of planets. Since core accretion is a slow process, it predicts that only stars older than a few million years have had time to produce planets and begin wobbling. On the other hand, disk instability is faster, creating planets around the youngest stars. If only the stars that are older than a few million years wobble, the test would favor core accretion; but if all infant stars in a cluster wobble, the test favors disk instability.

Doug Lin, a theoretical astrophysicist at the Lick Observatory in California, predicts that high-resolution mapping of protoplanetary disks around very young stars by the next generation of telescopes will allow astronomers to actually see planets forming. "It will be very exciting," says Lin. For now, Tremaine is happy to wallow in the uncertainty surrounding planet formation. He says, "All this confusion is a very positive sign that we are learning."

Theoretical astrophysicist and journalist Mark Sincell also writes for Science, Discovery Channel Online, *and* Earth & Sky Radio.

HUBBLEWARRIOR

Wendy Freedman rests in the eye of the storm of the great Hubble constant debate.

by Sally Stephens

THE IMPOSING, TWO-STORY BUILDING THAT HOUSES THE PASADENA offices of the Observatories of the Carnegie Institution of Washington stands in the middle of a residential street. In an office on its second floor, Wendy Freedman leans back in her chair, calmly talking about her research. Folders of data plots and piles of research papers cover her desk. On the bulletin board behind her, pictures of galaxies taken by the Hubble Space Telescope share space with snapshots of her family and drawings made by her two children. Dressed for the hot summer afternoon in a short-sleeved shirt, Freedman laughs and smiles easily as she talks. You'd never guess she's at the center of a heated debate.

The controversy surrounds one of astronomy's most fundamental numbers, the Hubble constant. In 1929, famed astronomer Edwin Hubble discovered that galaxies are speeding away from one another at velocities that increase with distance. The Hubble constant (H_0, pronounced "H naught") is a number that represents the rate at which those speeds increase. In other words, H_0 measures the expansion rate of the universe.

Wendy Freedman was coleader of the Hubble Space Telescope Key Project to measure the expansion rate of the universe. Wendy Freedman photo: Raleigh Souther / Background photo: Hubble Heritage Team (NASA/AURA/STScI)

By the late 1980s, reported values for the Hubble constant clustered around two widely divergent numbers, 50 and 100 kilometers per second per megaparsec. H_0 is written as the ratio of a galaxy's velocity away from us to its distance; a megaparsec is equivalent to 3.26 million light-years, meaning the universe expands 50 to 100 kilometers per second faster for each 3.26 million light-years farther out in space. Astronomers divided into two camps around the high and low values. Charges of ignored data, improper error corrections, and people being just plain wrong were thrown back and forth between the two groups. The debate often took on a personal tone, with ad hominem attacks mixed in with the latest scientific results.

JOINING THE FRAY

In 1984, Freedman joined the fray as one of three coleaders of the Hubble Space Telescope (HST) Key Project. Prior to the telescope's launch in 1990, NASA had designated the determination of the Hubble constant as one of the new telescope's "Key Projects," programs that addressed fundamental questions in astronomy and couldn't be done adequately with ground-based telescopes.

Knowing the Hubble constant, astronomers can calculate the age of the universe and gain insights into its past. For example, a high value of H_0 indicates that the speeds with which galaxies fly apart increases rapidly with distance. With these ever-increasing speeds, it wouldn't have taken long for the universe to have expanded to its present size, making it fairly young, say 8 billion to 10 billion years old. A low Hubble constant, on the other hand, implies the expansion happened slower. Thus, the universe would have taken longer to reach its present size, and so must be older, perhaps 18 billion years old.

Astronomers need two things to measure the Hubble constant: the speeds with which galaxies move apart and their distances. It's relatively easy to measure velocities from the shift in a galaxy's spectral lines caused by the expansion of the universe. Finding distances has proven much more difficult.

The HST Key Project's primary goal was the discovery of Cepheid variable stars that could be used to determine accurate distances to nearby galaxies. These luminous stars dramatically brighten and fade at regular intervals; the longer the period of variation, the intrinsically brighter the star. Comparing a Cepheid's observed brightness with this absolute luminosity gives its distance and, therefore, the distance to its parent galaxy. Galaxies with Cepheid-determined distances can then be used to calibrate other distance methods — a process known as the Cepheid distance scale — ultimately leading to a value for the Hubble constant.

Freedman had worked on the Cepheid distance scale as a postdoc at the Carnegie Observatories. Born and raised in Toronto, Ontario (she is now an American citizen), she had always been interested in science, even as a child. "I would spend hours in the basement with this chemistry set that they probably don't even allow anymore because of the toxic chemicals," she recalls with a laugh. Her father, a psychiatrist, shared his interest in astronomy with his oldest child. A high-school physics teacher further encouraged her, lending her a telescope and helping with a project on star formation.

Still, when she started as a freshman at the University of Toronto in 1975, Freedman planned to study biophysics. "Astronomy was like a hobby," she says. But her first classes did not go as expected. "The biology class was *huge*," she remembers. "It was in a lecture hall with about a thousand people in it . . . it was unbelievably, appallingly bad." Conversely, a first-year astronomy class was smaller and much more interesting. So she changed her field. "I ended up in astronomy, and I have never looked back."

By observing Cepheids with the Hubble Space Telescope, the Key Project team measured a distance of about 52 million light-years for M100 in the Virgo Cluster. Anglo-Australian Telescope Board/Photography by David Malin

AN INCONSTANT CONSTANT

The term "Hubble constant" is one of the most widely used in professional astronomy. But it's a misnomer: The Hubble constant isn't constant. The expansion rate of the universe changes with time, so the Hubble constant only measures the expansion rate during the current epoch in cosmic history.

Gravity slows down cosmic expansion because every object in the universe is tugging upon every other object. Astronomers have coined the term "deceleration parameter" to describe this effect. If gravity were acting alone, the Hubble constant was higher in the past, and therefore the universe is younger than it would be without gravity.

But contrary to all expectations, two teams of astronomers observing Type Ia supernovae have recently found strong evidence that the universe's expansion rate is actually accelerating (see "Accelerating the Cosmos," October 1999). Nobody knows exactly what causes this acceleration, but it presumably results from the vacuum energy of empty space. If the expansion is accelerating, the Hubble constant was lower in the past. This makes the universe a few billion years older than the 12 billion years implied by the Key Project's Hubble constant of 71 plus or minus 7, which assumed the universe's expansion was decelerating — not accelerating.

"I think that these supernova results are very exciting," says Wendy Freedman. "But given the difficulties of these measurements, it will likely take some time to establish firmly whether the result is correct." — *Robert Naeye*

By observing Type Ia supernovae such as this one in galaxy NGC 4526 (bright spot at lower left), two teams of astronomers have found evidence that the expansion of the universe is accelerating.

High-z Supernova Search Team

MIXING CAREER AND MOTHERHOOD

After finishing graduate school at Toronto in 1984, Freedman moved to Pasadena for a Carnegie postdoctoral fellowship. When the three-year fellowship ended, Freedman was offered a faculty position at the Carnegie Observatories, the first woman ever asked to join the permanent staff at their Pasadena headquarters.

In Pasadena, Freedman's research focused on observing Cepheids with the latest detectors to calibrate their distances. She collaborated often with Barry Madore, a professor at the University of Toronto. The two had met when Freedman was a student at Toronto. "I knew she was good," he recalls fondly. They married in 1985, soon after she moved to Pasadena. "We both really love our field," she says. "And it's very nice to be able to share that."

But their jobs in Pasadena and Toronto kept them apart more than they would have preferred. "The commuting business wears thin pretty fast," Freedman says. When she took the staff position at Carnegie, Madore quit his tenured job in Toronto to move to California. "That could have fallen through," he says, "but it didn't." Within a year, he managed to establish a position at Caltech running the NASA Extragalactic Database (NED), an on-line information service about galaxies. This past summer, he also joined her on staff at the Carnegie Observatories.

Hubble's sharp eye could resolve Cepheids (boxed) in the spiral arms of NGC 4603 (inset). The Key Project team measured a distance of about 108 million light-years. Jeffrey Newman (University of California at Berkeley) and NASA

The couple have two children, Rachael, 12, and Daniel, 11. Freedman admits to worrying about juggling career and family, until a friend advised her, "If you want kids, have them." Rachael was born two months before she was offered the staff job at Carnegie. "The year I was applying for jobs, I was pregnant," she remembers, beginning to laugh. "Morning sickness, traveling around the country. It was great fun." Freedman has no regrets about mixing career and motherhood. "The joys for me of both are enormous," she says. "I can't imagine a life without one or the other." Madore agrees, adding that they've been fortunate. "We had luck," he says. "We had help. We had each other. And we've had success."

THE KEY PROJECT

Their successful research on Cepheids took Freedman and Madore to a 1984 meeting in Aspen, Colorado, on the extragalactic distance scale. While there, they joined with other astronomers to form the core of the group that would become the HST Key Project team. At the time, Freedman

MEASURING THE UNIVERSE

The HST Key Project used four secondary distance methods to calculate the Hubble constant, because Cepheid variable stars aren't bright enough to be seen in galaxies farther than about 80 million light-years. Astronomers need galaxies more distant than that to be sure they're measuring "true" velocities caused by the expansion of the universe. Gravitational tugs from neighboring galaxies and galaxy clusters can change the observed motions of galaxies. Because expansion velocities increase with distance, these tugs become a smaller fraction of the overall velocity the farther away you go. To be sure they're looking far enough away to minimize these gravitational tugs, astronomers have to observe galaxies that are too far away to see Cepheids.

The four distance methods used by the Key Project give relative distances, for example, telling astronomers that one galaxy is four times farther away than another. But these methods cannot yield actual distances. For that, astronomers need galaxies with observed Cepheids. If you can find Cepheids in a galaxy that has also been measured via one of the other methods, you can nail down not only the distance to that one galaxy, but to all other galaxies whose distances relative to that one are known.

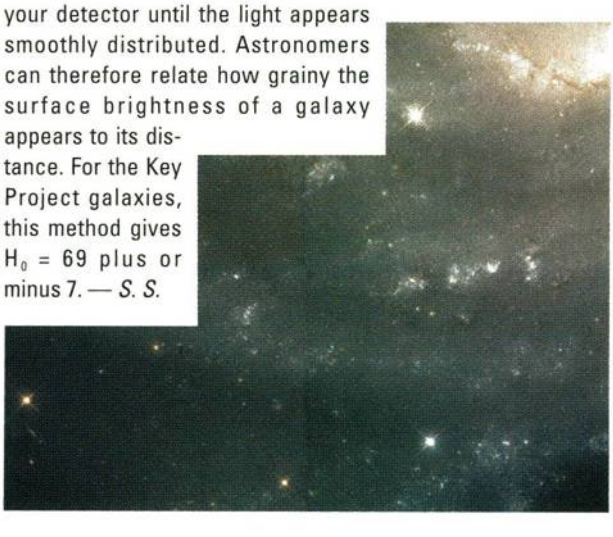
The secondary distance methods used by the Key Project team are:

1. Type Ia supernovae: These catastrophic explosions occur when material accreting onto a white dwarf from a companion star causes the white dwarf to explode. The brightest of these supernovae take the longest to fade, providing a way to gauge the relative absolute brightness of one compared to another. For the Key Project galaxies, this method gives $H_0 = 68$ plus or minus 6 kilometers per second per megaparsec.

2. Tully-Fisher relation: Named after the two astronomers who first used it to obtain distances, this method relies on the fact that how fast spiral galaxies rotate is related to how massive and therefore how bright they are. The faster the rotation, the inherently brighter the galaxy. For the Key Project galaxies, this method gives $H_0 = 71$ plus or minus 8.

3. Elliptical galaxy fundamental plane: This method is analogous to the Tully-Fisher relation but applies to elliptical galaxies. In this case, the brightness of elliptical galaxies correlates with the velocities of their constituent stars. An elliptical galaxy with a wide variety of stellar velocities is inherently brighter. For the Key Project galaxies, this method gives $H_0 = 78$ plus or minus 10.

4. Surface brightness fluctuations: This method stems from the fact that nearby galaxies appear "grainier" than more distant ones. That's because you can resolve individual stars in nearby galaxies. As you look at increasingly more distant galaxies, more and more stars will fill the same field of view on your detector until the light appears smoothly distributed. Astronomers can therefore relate how grainy the surface brightness of a galaxy appears to its distance. For the Key Project galaxies, this method gives $H_0 = 69$ plus or minus 7. — *S. S.*



NGC 4535 image: Lucas Macri (CfA), the HST Key Project, and NASA and Madore knew more about Cepheids than others on the team. "Basically the determination of the Cepheid distances was in our hands," says Madore.

Because of her extensive experience working with the latest detectors, Freedman's job once HST was up and running was to figure out how to convert the raw data to usable information. "She worked 20 hours a day, all hours of the night, getting those early galaxies done," says Madore. Her work established procedures for handling the data that other team members later followed.

Freedman also brought to the Project an acute awareness of the importance of rigorous and honest error analysis. "I am somebody who worries about systematic errors," she admits with a smile, referring to errors that are inherent to a method of observation. Reddening, the way dust scatters light, is an example of a systematic error. No matter how accurate an observation, if uncorrected, reddening will always make an object appear dimmer than it really is.

Freedman thinks astronomers working on the Hubble constant have traditionally underestimated their errors. "I don't think there ever would have been such a big controversy," she says, "if people had done the error analysis well to begin with. They would have had overlap in the error bars." Error bars express the estimated range of uncertainty in a measurement. A Hubble constant, for example, might be expressed as 70 with an error bar of plus or minus 7. This means the team thinks the Hubble constant could lie anywhere between 63 and 77.

Yale University astronomer Brad Schaefer agrees with Freedman, up to a point. "The scientists themselves were . . . reporting their errors as best they knew," he explains. "But there were systematics they didn't know about, which they could not include in their reported error bars."

In 1994, the Key Project team published its first result, based on observations of one galaxy, M100 in the Virgo Cluster. In the paper, Freedman and her colleagues quoted a value for H_0 of 80 plus or minus 20 percent. The errors seemed high, but, in keeping with Freedman's commitment to "honest" error analysis, were what Freedman and her colleagues felt they could justify. Their result implied an age for the universe of 8 billion to 12 billion years (depending on its average density), compared to stars in globular clusters that were then thought to be 13 billion to 17 billion years old. How could the universe be younger than its oldest stars?

The Key Project astronomers knew their result was preliminary and said so. But the media didn't listen to the caveats and, instead, seized on the age discrepancy in articles about the "crisis in cosmology" that implied the big bang model no longer worked. "That was blown way out of proportion," recalls Freedman. Research in the last few years and results from the European Hipparcos satellite have reduced the ages of the oldest globular clusters, and the age discrepancy and "crisis" are no longer considered an issue.

FINAL RESULTS

After that first paper, the Key Project continued to observe more Cepheids. Together with Jeremy Mould of the Australian National University and Robert Kennicutt from the University of Arizona, Freedman oversaw a team of 27 astronomers at 13 different U.S. and international institutions. "We could not have done this before e-mail," she laughs. In addition, the entire team met face-to-face several times a year. Managing such a large group has been likened

The Coma cluster is so distant that astronomers can't see its Cepheids. By using secondary distance indicators, the Key Project astronomers estimate a distance of 340 million light-years. Kitt Peak National Observatory to herding cats, and Freedman admits, "There was a time when I couldn't even imagine we would see the end."

"Before HST, we could observe maybe five galaxies that were useful for measuring the Hubble constant," Freedman says. Over the course of the eight-year project, the Key Project team observed nearly 800 Cepheids in 18 galaxies and used them to get distances to those galaxies. They then used the Cepheid galaxies to calibrate four other distance methods (see "Measuring the Universe," page 57).

Finally, on May 25, 1999, Freedman and Mould announced at a NASA press conference that the Key Project team had measured its final value for the Hubble constant: 71 plus or minus 7. This gives a best estimate for the age of the universe of 12 billion years. That's consistent with the ages of the oldest globular-cluster stars.

Critics and proponents alike agree the Key Project made great strides forward. "Just getting Cepheid distances to a bunch of nearby galaxies is fundamental new data," admits Abhijit Saha from the National Optical Astronomy Observatories, even though he has criticized the Key Project's inclusion of some secondary distance methods that he considers unreliable.

THE HUBBLE DEBATE

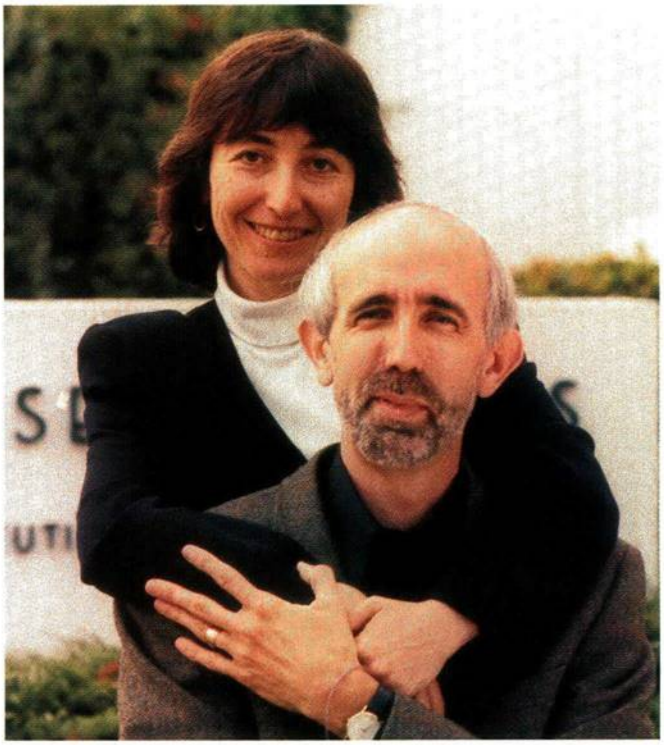
Hopes that the HST would resolve the Hubble constant debate once and for all proved premature. The HST Key Project's result of 71 plus or minus 7 placed the team squarely in the high-Hubble-constant camp. However, Allan Sandage, the most vocal proponent of a low Hubble constant, who works on the same floor at the Carnegie Observatories in Pasadena, continues to insist H_0 is 58 plus or minus 2 (which yields an age of about 15 billion years). Sandage uses only Type Ia supernovae, calibrated by Cepheid distances, in his research. But he includes older supernovae recorded on photographic plates before World War II that Freedman and her team don't trust. The two groups also disagree on the processes by which their data are analyzed.

Sandage's quoted errors don't include estimates of external systematic errors. Freedman argues that if systematic errors are included, "The uncertainties of the two groups' measurements overlap. It's very hard to say there's still a significant disagreement." For her, the two sides have converged and now agree to within the 10 percent uncertainties.

Astronomer Saha disagrees. He has worked with both Sandage and the HST Key Project team and thinks the same systematic errors effect both groups, changing both teams' values by the same amount and in the same direction. "If one went up, the other one would go up too," he explains. According to Saha, if systematic errors are removed from the published results, the Key Project's errors will drop significantly, and any overlap between the two groups' error bars disappears. "The difference between 60 and 70 is not just errors," he declares. For him, as for Sandage (who declined to be interviewed for this article), the Hubble debate continues.

Other astronomers have independently tried to determine the Hubble constant. "In the last three years, all but a few reported Hubble constant values are consistent with H_0 in the low 60s, give or take," Schaefer says. "Virtually everyone is somewhere between 55 and 70."

Regardless of who is ultimately proven right, no one disputes that the debate has narrowed considerably. Before HST was launched, the high and low values of H_0 were 100 and 50, a difference of a factor of two. Now the disputed values have errors of plus or minus 10 percent. "I think that's great progress," says Freedman.



Freedman and her husband Barry Madore have successfully mixed astronomy careers and family life. Raleigh Souther

WHERE WE GO FROM HERE

Most astronomers agree the Hubble debate will continue. "I think we will argue at this 10-percent level for awhile," cautions Freedman. If she's bothered by Hubble-debate criticism of her personally, it doesn't show. "That's the way science proceeds," she says philosophically. To resolve the debate, she adds, "We'll need more accurate distance indicators, and we don't have them right now."

But astronomers may have them within the next few years. By measuring fluctuations in the cosmic microwave background and time delays in gravitational lensing, and by using radio interferometry to study sources in other galaxies, astronomers hope to gain independent values of H_0, that is, ones that don't rely on Cepheids for calibration. If these new methods provide consistent results, Schaefer says, "then there will be a time to declare a victory in the debate."

In the meantime, Freedman plans to move on. "The Key Project has been enormously time-consuming," she says. For her, the end of the Key Project comes at an opportune time. Within the next year, the Carnegie Observatories will finish building two 6.5-meter telescopes at Las Campanas in Chile. "I plan to spend a lot of time observing with those," she says.

She's also looking forward to spending more time with her family and doing more reading, swimming, and ice skating. Still, she says, "The opportunities to make observations where you actually confront cosmological theories makes it a very exciting time to be working in the field. I love what I do." A

Former Mercury *magazine editor Sally Stephens is now a freelance writer based in San Francisco.*

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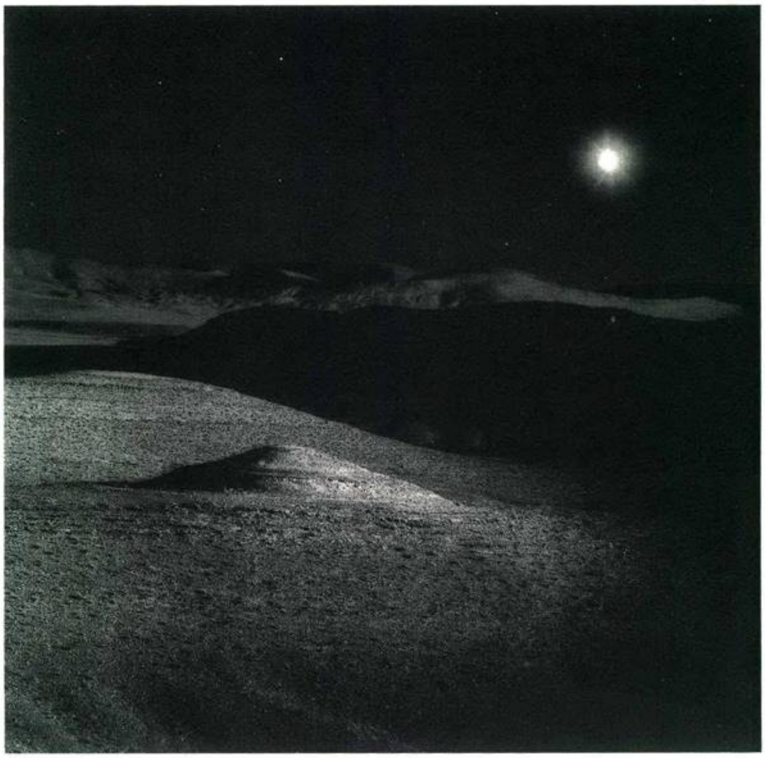
NIGHT VISIONS



Over a period of almost seven years, I spent hundreds of nights camped under the starry night sky of the vast and magnificent Sinai desert, where I often wandered along the dry riverbeds with only starlight to guide me. The moon, when it was out, was almost blinding in its brilliance. The photographs I made during the day went into my book *In a Desert Land: Photographs of Israel, Egypt, and Jordan*. The images of the night landscape remained in my head, haunting me for years. But I knew that the long exposures necessary to expose the darkened landscape would result in star trails — that the image in my mind's eye would not be transferred to film. So those photographs remained just an idea.

Meanwhile, the digital revolution was on its way, and I wrote the text for *In a Desert Land* on a Macintosh Plus that I purchased with the advance from the book. By the time I was ready to edit the images for my next book (*And I Shall Dwell Among Them: Historic Synagogues of the World*), I was able to make color corrections in Photoshop. Here, I realized, was the tool I needed to photograph the night landscape as I had seen it. The photographs could be made by compositing a

(continued on page 68)

TEXT AND PHOTOGRAPHS BY NEIL FOLBERG

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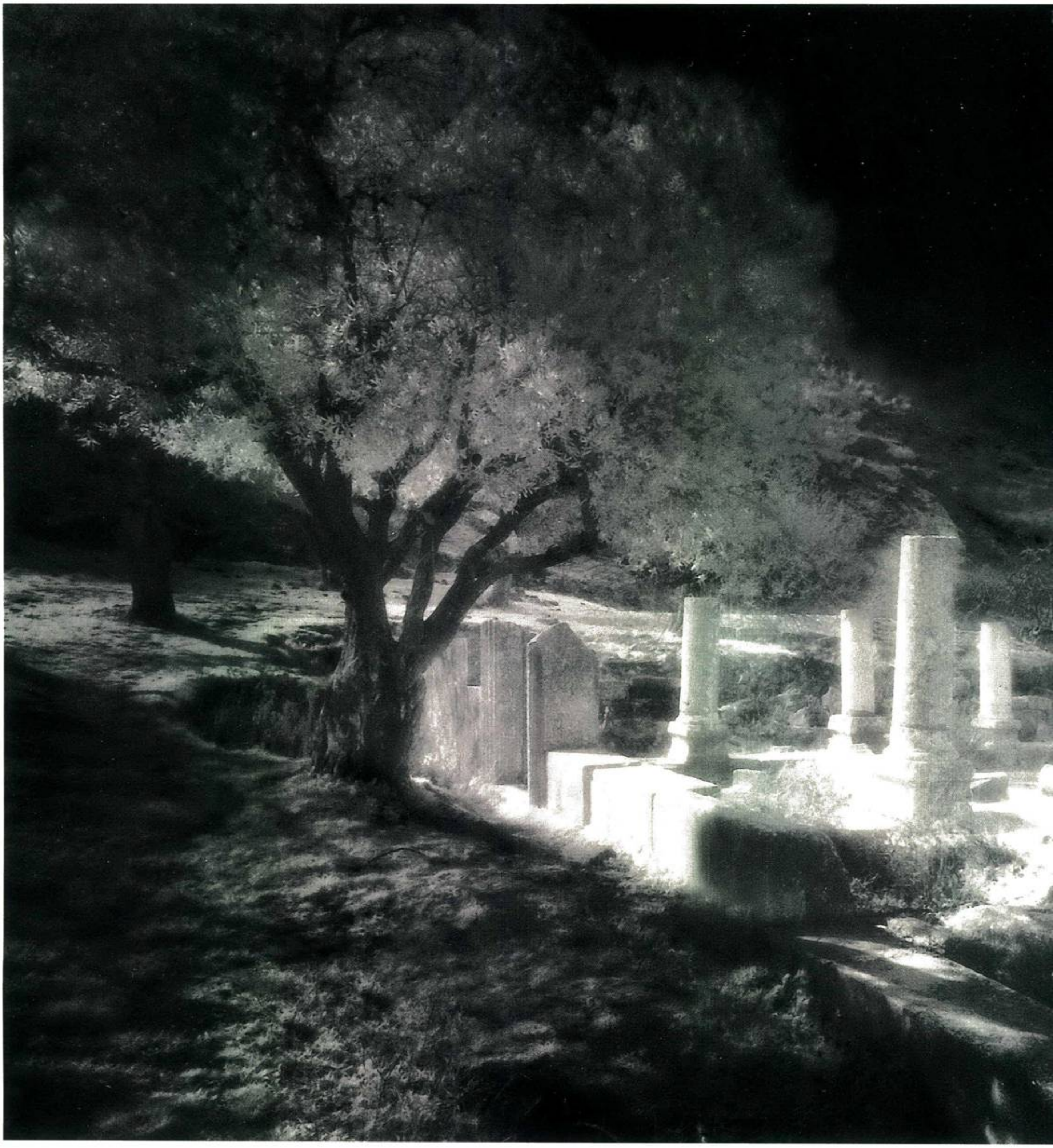

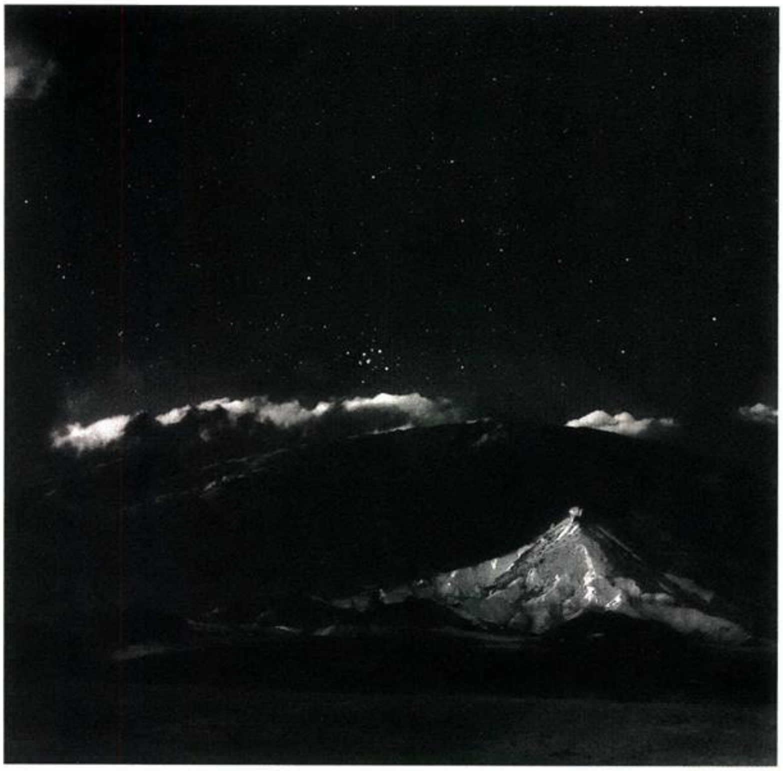

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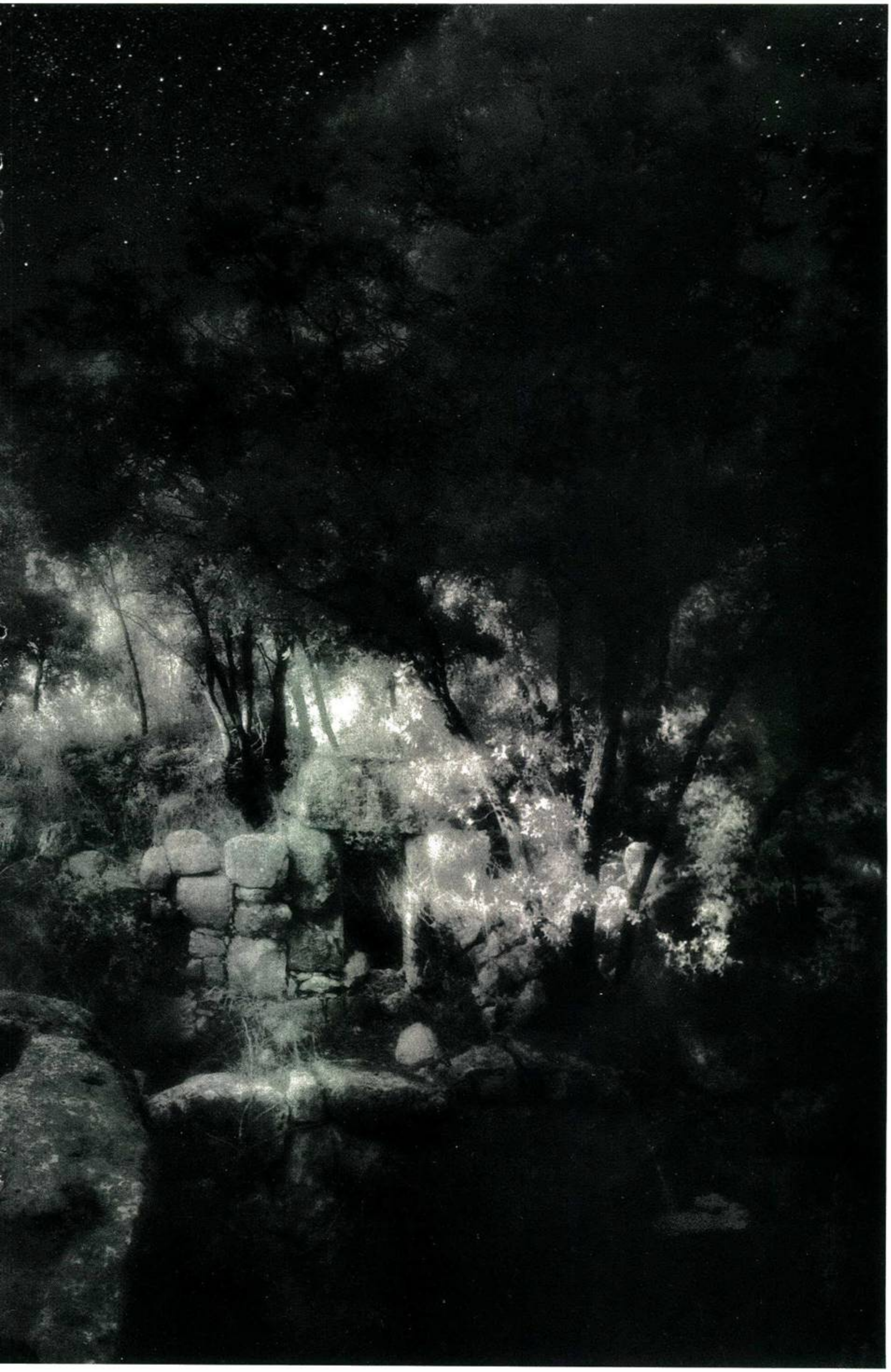

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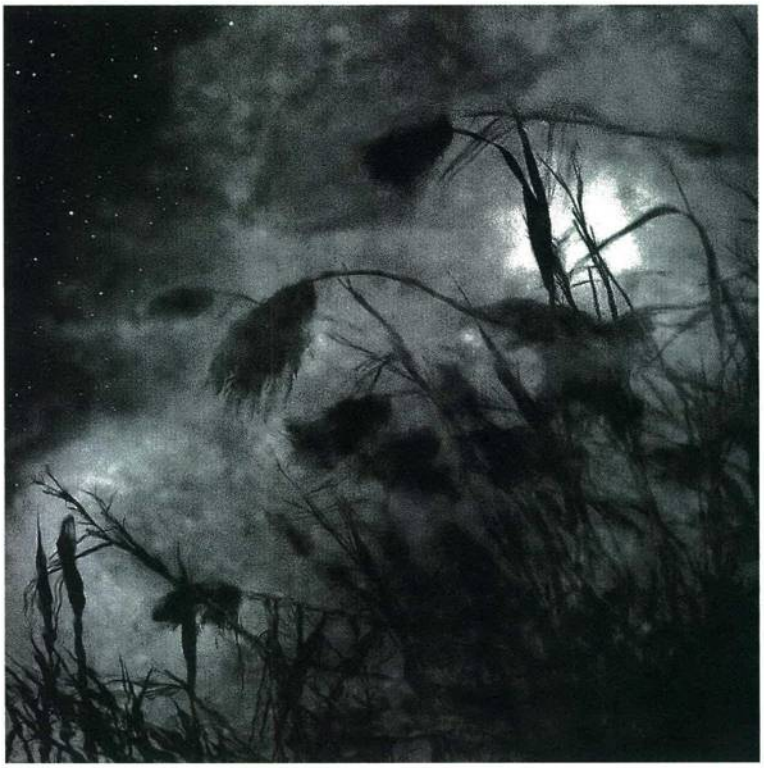

EIN SAHARONIM

photograph of the landscape together with a photograph of the starry sky. With the help of two amateur astronomers in Israel, John Dan and Yossi Huri, I learned to make guided piggyback photographs on the porch of the Wise Observatory, at the edge of the Ramon Crater in Israel's Negev Desert. The observatory, which is operated by Tel Aviv University, has a 1-meter telescope that is hooked up to a CCD camera. Its darkroom lay virtually untouched for years; now I put it to good use, developing my hypered film on the spot before it could be damaged by humidity.

The landscape at my feet was a perfect setting: a large, moonlike crater created by such unique geological phenomena that the accepted international term for such a formation is the Hebrew word "machtesh." Machtesh Ramon's lunar spirit is so strong that I actually named one of the photographs made there after a lunar "marsh," Palus Somni, the Marsh of Sleep. Ein Saharonim is a spring in the crater, and Har Pitam is a limestone structure just at the southern edge of the crater.

The ancient starlight shines also upon Israel's ancient landscapes and ruins, so I have sought out antiquities such as the 3rd-century Galilean synagogue at Gush Halav, the Nimrod Fortress on the Golan Heights (Corona Borealis) and an ancient olive press on the northern border. So while this new work has some element of place — the ancient/modern land of Israel — it also goes far beyond locality, well beyond the reach of humanity.

You might think that these manipulated landscapes are a distortion of reality, but I consider them to be an accurate reflection of what the eye sees and what at least one heart feels. Our feet are planted in the sand, but our vision encompasses the universe and sometimes more. These are the scenes, on the human edge of the cosmos, that I am showing in my photographs.

Neil Folberg's limited edition Starry Nights prints may be seen at Scott Nichols Gallery in San Francisco, Alan Klotz/Photocollect Gallery in New York and at Vision/Neil Folberg Gallery in Jerusalem. Neil Folberg can be reached at folberg@netvision.net.il.

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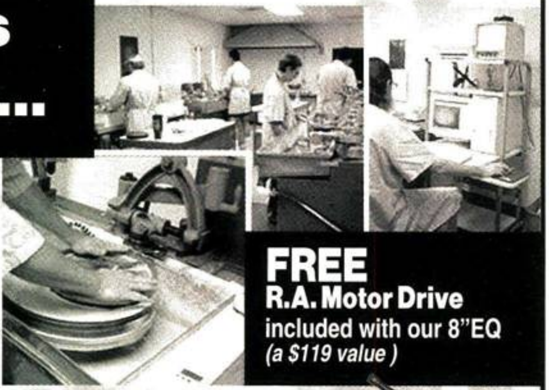

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Reaching for the Sun

How we learned to read the chemistry of stars and planets.

By James Trefil

Auguste Comte (1798–1857) is known today as an important philosopher and the father of modern sociology, but in his own lifetime he lived a shadowy kind of existence on the fringes of Parisian intellectual circles. I suppose it all started when he was expelled from the prestigious École Polytechnique — for a series of events that started when he was offended that an instructor talked to his students while he had his feet on his desk. When Comte's turn to recite came, he adopted a similar posture and, when reprimanded, is supposed to have said "I would have thought you would be pleased I was following your example."

Comte's life as a freelance intellectual allowed him to follow his thoughts on the subject that interested him most — the nature of

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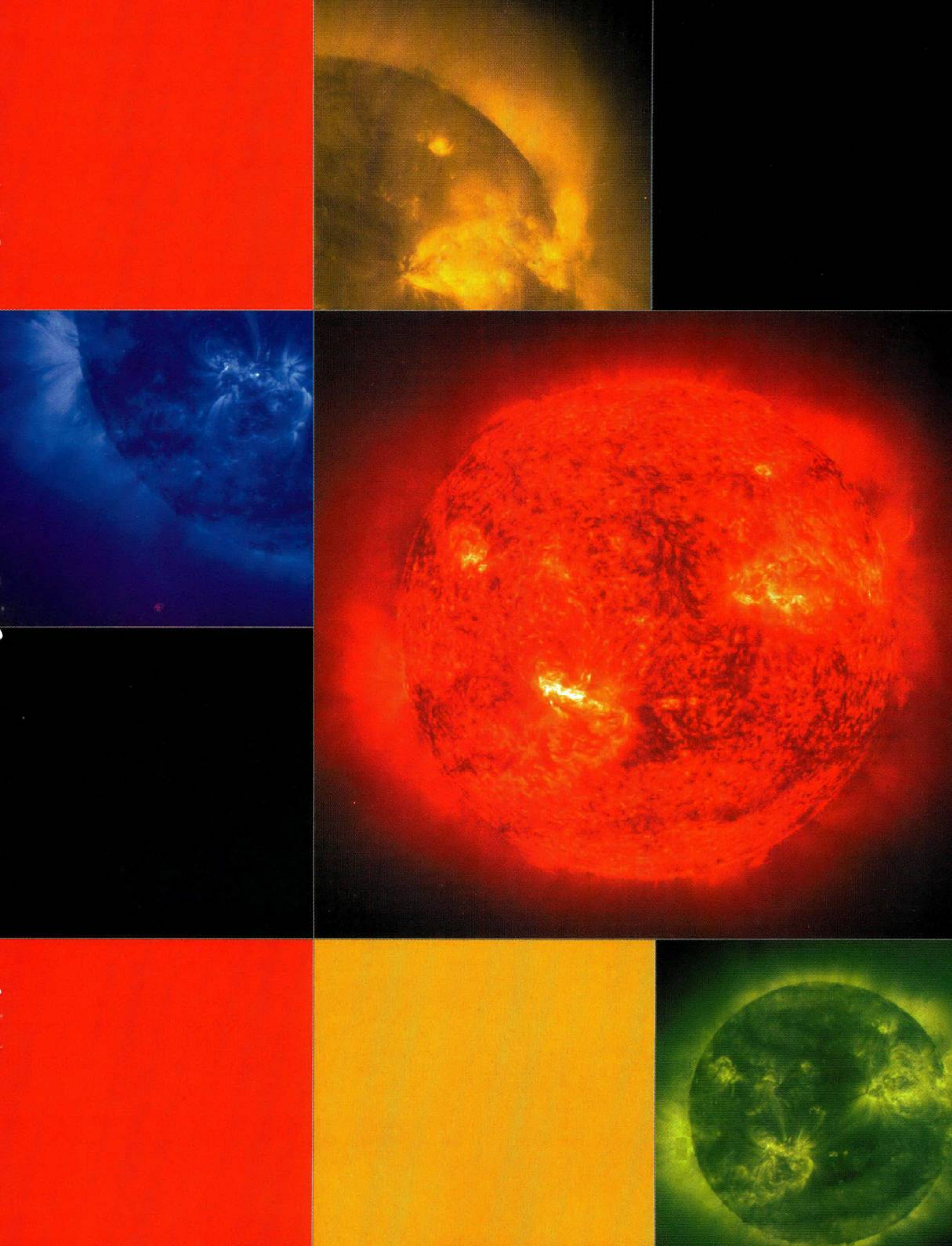
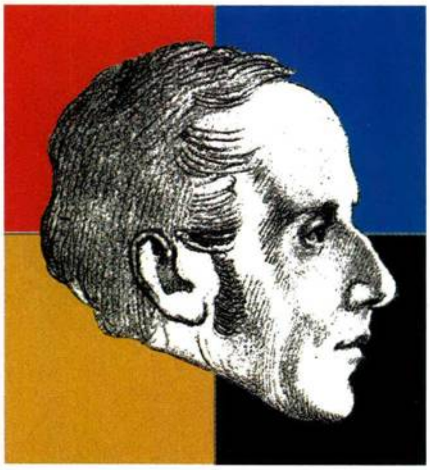


SO LONG AS ASTRONOMERS stick to measuring the motions of stars and planets in the sky, THEY ARE BEING SCIENTIFIC.

knowledge. He eventually formulated a theory in which knowledge develops in three stages: the theological (or mythical), the metaphysical (or abstract), and the "positive" (or scientific). That last, of course, was supposed to be the highest state of knowledge and was concerned only with making verifiable statements about observable phenomena. In his monumental work *Course of Positive Philosophy*, Comte surveyed all the sciences to see how far along his three-step progression they were.

So long as astronomers stick to measuring the motions of stars and planets in the sky, he argued, they are being scientific. However, even for the planets, he cautioned: "We see how we can determine their forms, their distances, their bulk, and their motions, but we can never know anything of their chemical structure."

And, as for the stars? "We can never learn their internal constitution." These sorts of pronouncements make sense provided that you believe that (1) the only way to find out what something is made of is to examine it in your lab, and (2) there is no way to obtain a chunk of planetary or stellar material. But even as Comte was formulating his grand scheme of scientific knowledge, events were taking place in a remote Bavarian workshop that were going to transform forever the way we think about the sky.



Joseph von Frauenhofer American Institute of Physics Emilio Segrè Visual Archives, W.F. Meggers Collection

In the early19th century, Europe was in the midst of the Napoleonic Wars and military needs were driving many technologies (as they often have before and since). In 1801, for example, the French military government in Bavaria was having a great deal of difficulty making a survey of Napoleon's new conquests because of the poor quality of the lenses available for surveyor's transits. Seeing an opportunity where others saw only a problem, farsighted businessmen bought an abandoned monastery, called Benediktbeuren, near Munich. There they set up a company to improve the quality of glass.

The problems these new manufacturers had to deal with were mundane — not at all the sort of thing that a grand philosopher such as Auguste Comte would think worthy of his attention. Glassmakers had to find ways of making sure that when they melted a mixture of quartz, lime, and soda in their furnaces, that the materials really mixed together uniformly. The inability to solve this problem caused windows in old buildings to produce distorted, wavy images of outside objects, and you can imagine what it did to telescope lenses.

Probably the smartest thing the company owners did was hire a journeyman glassworker by the name of Joseph von Frauenhofer. Orphaned as a young boy, Frauenhofer had been apprenticed to a glass cutter. One day while working, the building he was in collapsed around him, trapping him inside and, apparently, turning him into something of a public hero in Bavaria as rescue workers struggled to dig him out. The Elector of Bavaria gave him 18 ducats, which allowed Frauenhofer to buy out his apprentice's contract and acquire enough tools to set himself up in business. He apparently did quite well, because by 1813 he was in charge of the whole operation at Benediktbeuren.

In modern laboratories, there is usually one person around who really knows how things work, to whom everyone turns when things go wrong. We often say that this sort of person has "magic hands." Joseph von Frauenhofer was such a man. Over the years, one painstaking development at a time, he improved the quality of the glass produced by his factory, and he ended up producing the best optical equipment to be found anywhere in the world. Strangely enough, this gave Frauenhofer a new problem.

You have to remember that even for someone such as Frauenhofer, glassmaking was still more of an art than a science. There was no way, for example, that he could measure small differences in the composition of his glass from one melt to another, or even small differences in instrument components taken from the same melt.

To see why this might be important, think about a simple optical instrument such as a prism. When white light comes into a prism, the different wavelengths are bent through different angles, resulting in a spread of colors. Prisms made of slightly different pieces of glass, however, will bend the same wavelength of light through slightly different angles. Given this fact, consider what might happen if two laboratories in different parts of Europe measured the bending of light in a particular experiment and got different results. They would have to worry about whether the difference was real — something actually out there in nature — or the result of Frauenhofer selling them prisms made from slightly different mixes of glass.

What was needed was some sort of calibration standard — some fixed wavelength of light that both laboratories can run through their prisms to compare the way the instruments work. Today, of course, there are hundreds of such standards available, but in Frauenhofer's time there was nothing. He turned to a discovery that had been made in 1802. If you pass sunlight through a prism of sufficiently high quality, you notice a series of dark bands superimposed at irregular intervals over the colored spectrum of light. No one at the time (including Frauenhofer) had any idea what these lines were, but he realized that whether he understood them or not, they could be used to solve his calibration problem.

The same sun shines on London and on Berlin. If the wavelengths of the dark bands were measured carefully, then laboratories in those two cities could compare their prisms by looking at how much they each bent a specific wavelength. (In practice, of course, they would probably compare many lines and many wavelengths.) This done, they could then compare results confident that what they were investigating was not the result of someone putting a little more lime in a melt at Benediktbeuren.

Like most high-tech entrepreneurs before and since, Frauenhofer was not slow to exploit his new idea. By the 1820s, he had made careful measurements of no fewer than 574 dark lines in the sun's spectrum, providing a detailed road map for other investigators to follow. As far as we can tell, he never tried to find out what the lines were or where they came from. For him, they were useful markers that made his work as an equipment manufacturer easier. Today, we honor his careful benchmark investigations by referring to dark lines of this type as "Frauenhofer lines."

Looking at Light

For more than half a century, the sun's Frauenhofer lines remained a useful (but unexplained) phenomenon, and the focus of our story shifts from glassmaking to new developments in the science of chemistry. By the late 1850s, the University of Heidelberg had become one of the great centers of scientific research in the world, and two of its brightest scientific stars were a physicist named Gustav Kirchhoff and a chemist named Robert Bunsen.

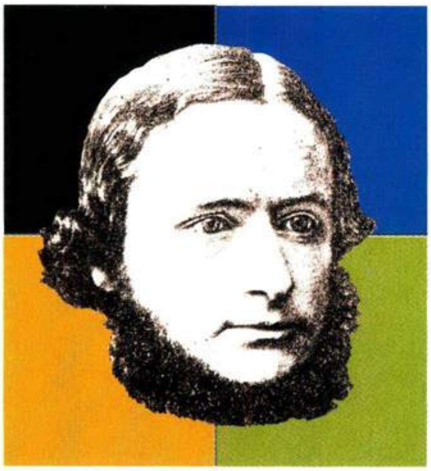
Bunsen invented the burner found in practically every high school chemistry lab. He was an expert in what is called analytical chemistry, the branch of the science devoted to purifying and identifying samples of chemical compounds. He cut his eyeteeth doing detailed chemical analyses of the gases produced in the manufacture of cast iron. By the 1850s, he was at Heidelberg working on techniques for identifying gases by looking at the color of the flames they produced when burned. The Bunsen burner was developed so that metal samples could be burned in a hot, nonluminous flame.

Meanwhile, Gustav Kirchhoff was beginning a parallel career through the German university system. In 1847, he graduated from the University of Konigsberg and married the daughter of his professor ("thus fulfilling," one author noted snidely, "the two prerequisites for a successful academic career"). At the age of 21, he formulated the laws that govern the voltages and currents in electrical circuits (laws that still bear his name), and in 1854 he went to Heidelberg. In talks with Bunsen, he suggested that instead of just looking at the colors of the flames, they should look at the spectrum of light being emitted. It had been known for some time that the light from burning materials, when passed through a prism, splits up into a series of sharp lines (called spectral lines), rather than a continuum, as happens with sunlight. What Kirchhoff suggested was that those bright lines would make a good "tag" by which to detect fine distinctions between different compounds.

The two took this idea seriously and put together the world's first instrument for analyzing spectra from a couple of old telescopes, a prism, and a cigar box. The idea was to look at light from burning materials in a systematic way, cataloging the positions of various spectral lines.

During the run-up to the main experiments in the autumn of 1859, however, Kirchhoff stumbled on an observation that was to change the face of astronomy. He was running sunlight through their apparatus, looking at Frauenhofer lines. He had already detected a correspondence between the bright lines in the light from burning metals and the dark Frauenhofer lines. What he noticed, however, is that if he passed sunlight through a sodium flame before bringing it into his apparatus, certain Frauenhofer lines got darker.

After mulling this finding over for a night, Kirchhoff realized that the dark lines occurred when light absorbed atoms. Frauenhofer lines were created when white light from the sun's core was absorbed by sodium atoms in the solar atmosphere. Even more of that light was absorbed by Kirchhoff's flame, which is why the lines got darker. This not only explained a fundamental property of radiation, it opened a new window on the universe. For the first time in history, a human being had detected the presence of a specific chemical element (sodium) on a nonterrestrial body.



Gustav Kirchhoff Photo Meisenbach, Leipzig, courtesy American Institute of Physics Emilio Segrè Visual Archives

Today we know that the atom has a heavy, positively charged nucleus around which electrons move in specified orbits. When an atom jumps from a higher orbit to a lower one, light is emitted, and the energy of the light moving away from the atom is precisely equal to the difference in energy of the electron in the two orbits. When an atom absorbs light, on the other hand, the electron jumps from a lower to a higher orbit, and the energy absorbed from the light is precisely equal to the energy needed to lift the electron up. Kirchhoff didn't know about electrons, of course (their discovery was decades in his future), but from his experiments he realized that an atom that emits a particular wavelength of light will also absorb at that wavelength.

Killer Instinct

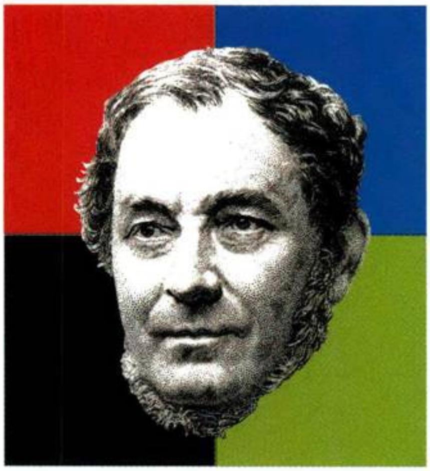
Armed with their new insight, Kirchhoff and Bunsen displayed the "killer instinct" you would expect from world-class researchers by identifying two new chemical elements — cesium (from the Latin for "sky blue") and rubidium ("dark red") — from drops of mineral water. (The elements were named for the brightest colors in their spectrum.) In the following years, an entire grab bag of elements was identified by spectra. The new elements included indium, gallium, scandium, germanium, and thallium (identified on the basis of a single spectral line). Today the creation of new transuranium elements is something of a

TODAY, A SPECTROMETER is as common as a TELESCOPE IN AN ASTRONOMER'S STUDIES.

cottage industry (we're at element 112 and counting), and identification of the handful of new nuclei created in accelerators is invariably done by spectroscopic analysis of radiation from the new atom or from the nucleus itself.

While chemists were using the newfound ability to analyze spectra to flesh out the periodic table, young astronomers were not slow in applying the analysis of spectra to the study of the heavens. In fact, the adoption of the technique was so rapid that to many older astronomers it seemed as if the field that they knew and loved — the field devoted to the study of the motions of objects in the sky — was being abandoned. As one text widely used by amateur astronomers at the time put it, "With all my admiration for the marvelous powers of chemistry . . . I really trust that it will not be asserted . . . to the disservice and detriment of the measuring agency. . . ."

One amateur astronomer in England, Norman Lockyer, acquired a small spectroscope to fit his 6-inch backyard telescope and used it to make a series of stunning discoveries about the sun. Examining light from sunspots, he noted that the Frauenhofer lines were darker than those from neighboring areas, demonstrating that sunspots are cooler than their surroundings. He used the spectroscope to make the first observation of a solar prominence in the absence of an eclipse and discovered and named the solar chromosphere (so named because of the bright-red hydrogen spectral line that created its image). For these discoveries, Lockyer, who made his living as a science writer and clerk in the War Office, was elected to the Royal Society.



Robert Bunsen American Institute of Physics Emilio Segrè Visual Archives, E. Scott Barr Collection

Then, in 1868, he made a rather startling discovery. In the spectrum of the sun, nestled between two bright-yellow sodium lines, he saw a spectral line that just wasn't supposed to be there. At least, it didn't belong to any element that chemists knew about. Lockyer concluded that what he was seeing was a new element — one that didn't appear to exist on Earth. He named the element helium (from helios, the Greek word for sun). The attention that Lockyer received for this discovery may have played a far-reaching role in the development of science, because a year later he was able to bring out the first edition of the journal *Nature*. Since 1869, this magazine has been an important means of communication within the scientific community, and Lockyer served as editor for its first 50 years.

From the late 1860s on, the scientific community was confronted with a rather unusual dilemma. On the one hand, spectroscopy was turning up new chemical elements right and left in materials found on Earth, and in every case, sooner or later chemists were able to get enough of the material together to subject it to standard laboratory tests. This could be a difficult and tedious procedure — it took 40 tons of mineral water, for example, to produce enough rubidium and cesium to put in a test tube — but it was always possible to do it. Helium, however, stubbornly refused to show up no matter how hard people looked for it. The possibility that a chemical element might exist in the sun's atmosphere that wasn't found on Earth couldn't be ignored, and the possibility had disturbing implications.

One of the foundations of modern astronomy is that we can discover the nature of celestial bodies by doing experiments on Earth. Isaac Newton's greatest contribution to science, after all, was probably the realization that it was the same force of gravity that made the apple fall and kept the moon in its orbit. What would it mean if it were impossible to do experiments on Earth to find out how things behaved on the sun? It would have vindicated Auguste Comte's original declaration.

As it turned out, however, this problem never arose. In 1892, scientists making precision studies of Earth's atmosphere discovered that small amounts of hitherto unknown gases are part of its chemical composition. The first gas found in this way was argon (it makes up about 1/2 of a percent of the atmosphere), and the discovery triggered a search for new and rare gases. In 1895, Lockyer examined gas from a sample of uranium ore, and in his words, "One by one, the unknown lines I had observed in the sun in 1868 were found to belong to the gas I was distilling (from the ore)." So despite its name, helium existed on Earth as on the sun, and an intellectual crisis was averted.

Today, the use of spectra to analyze the chemical composition of celestial objects is so widespread that a spectrometer is as common as a telescope in an astronomer's studies. But the introduction of spectroscopy by Kirchhoff and Bunsen marked the transition from astronomy to astrophysics — between worrying about where objects are in the sky to worrying about what they are.

This was the first example of the shift from describing what we see in nature to explaining it in terms of the fundamental laws of physics and chemistry. In our own century, we have seen another such event, as geology transformed itself into geophysics. In fact, when it's late at night at the faculty club and I want to annoy my colleagues, I say the true goal of any science should be to make itself into a branch of physics.

When they want to annoy me, they point out that this sort of generalization led Comte astray 200 years ago.

James Trefil is a member of Astronomy*'s Editorial Advisory Board.*

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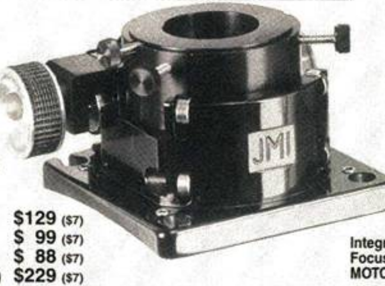

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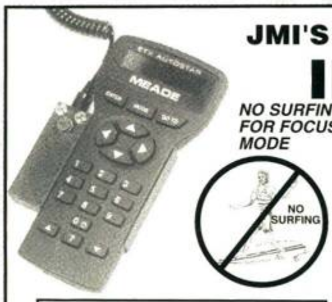

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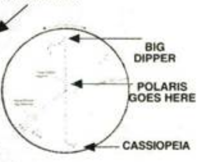

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THE SKY SHOW

Winter closes with a stunning conjunction, and spring returns with warmer nights.

by Martin Ratcliffe and Alister Ling

▶ The best evening conjunction of the year occurs in March as three planets quickly close in on each other. **Mars**, **Jupiter**, and **Saturn** begin the month spread out in the eastern sky, stretching over 28°. The slender crescent moon stands nearby Mars on March 8 and Jupiter on March 9, adding to the splendor of the planetary conjunction. By March 31, these planets are separated by just 9°. Jupiter, the brightest, stands in the middle of the trio. Shining at magnitude 1.4, Mars appears dimmest of the three because it is lowest in the sky in bright twilight. Saturn, a full magnitude brighter than Mars, lies highest above the horizon.

Jupiter makes an especially attractive target in the twilight of early evening. Just after sunset when the planet becomes visible, small telescopes will show the four major moons and the fine, delicate detail of the clouds and zones in the turbulent atmosphere. Note especially the South Equatorial Belt, which telescopic observers see as the upper dark belt of the two that are easiest to view in the inverted image of Jupiter. Remarkable activity takes place in and around this region of the planet, partly due to the presence of the famous Great Red Spot. Jupiter has dimmed a whole magnitude since its close opposition last year and shines at magnitude 2.0 by the end of March. Its disk has shrunk noticeably also, to 34". Both Jupiter and Saturn lie in the constellation Aries the Ram.

Saturn's disk spans only half the size of Jupiter's, and because the two planets are close in physical size, the apparent size indicates that Saturn is almost twice as far away as Jupiter. Saturn's rings outstrip Jupiter's girth, however, and their long axis extends a full 38". (For more on this conjunction, see "A Public Display of Affection," page 81.)

The sun follows a path around the sky called the ecliptic, and this month the ecliptic is well defined by the line of planets in the western sky. Higher in the sky lies the Pleiades, or Seven Sisters, a fine open cluster of stars in Taurus the Bull. Designated M45, the Pleiades lies a little north of the ecliptic plane. From very dark sites it is possible to see the zodiacal light — a cone of light extending up past M45 at times. Viewing this elusive glow is made possible by the high inclination of the ecliptic, and March is the best time in the Northern Hemisphere in which to see it (see "A Pyramid in the Sky," page 83).

The sun's motion takes it past the First Point of Aries, an artificial location in the sky defined in our coordinate system as the place where the ecliptic and celestial equator meet. It marks the zero point of the Right Ascension grid — the celestial equivalent of longitude on Earth. Due to the

Frank Zullo

The crescent moon bathed in earthshine along with Venus and Jupiter line up on the ecliptic in a dawn sky over Saguaro Lake, Arizona.

MARCH 2000

1 Mercury is in inferior conjunction, 10 A.M. EST

2 The moon passes 0.4° south of Neptune, 7 P.M. EST

3 Venus passes 0.07° south of Uranus, 7 P.M. EST
The moon passes 0.7° south of Uranus, 8 P.M. EST
The moon passes 0.6° south of Venus, 8 P.M. EST

6 New moon is at 12:17 A.M. EST

8 Asteroid Eunomia is at opposition, 6 A.M. EST
The moon passes 5° south of Mars, 9 A.M. EST

9 The moon passes 4° south of Jupiter, noon EST (page 81)

10 The moon passes 3° south of Saturn, 4 A.M. EST

13 First quarter moon is at 1:59 A.M. EST

14 The moon is at perigee (229,617 miles from Earth), 6:40 P.M. EST
Mercury passes 2° north of Venus, 7 P.M. EST

19 Full moon is at 11:44 P.M. EST

20 Vernal equinox is at 2:35 A.M. EST

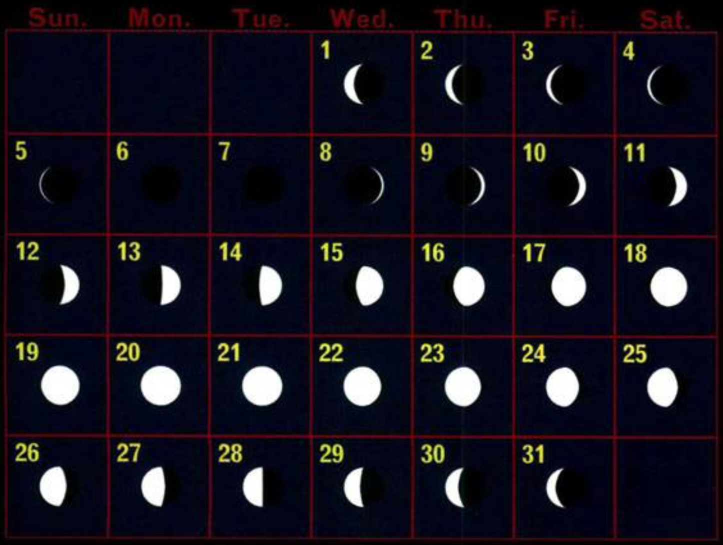
22 Asteroid Ceres is at opposition, 4 A.M. EST (page 82)

27 The moon is at apogee (251,138 miles from Earth), 12:21 P.M. EST
Last quarter moon is at 7:21 P.M. EST

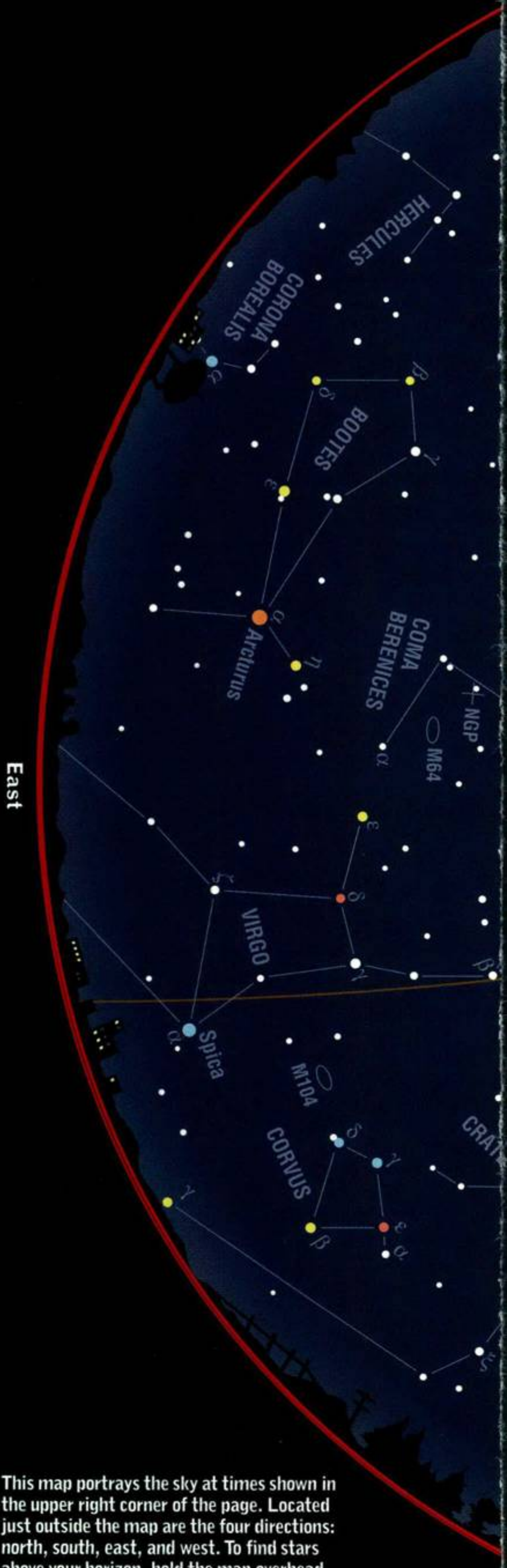
28 Mercury is at greatest western elongation (28°), 4 P.M. EST

30 The moon passes 0.7° south of Neptune, 5 A.M. EST

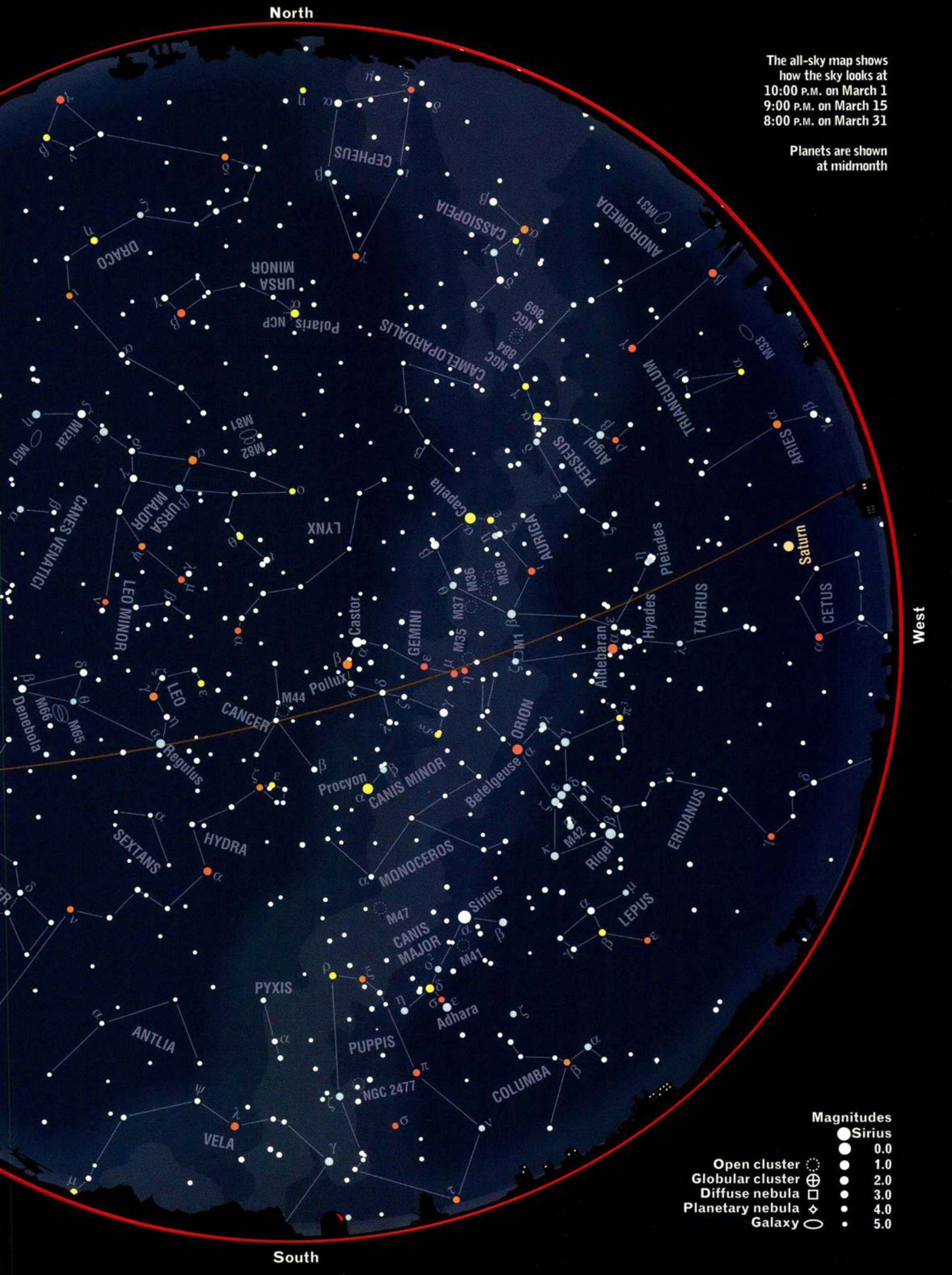
31 The moon passes 1.0° south of Uranus, 7 A.M. EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	



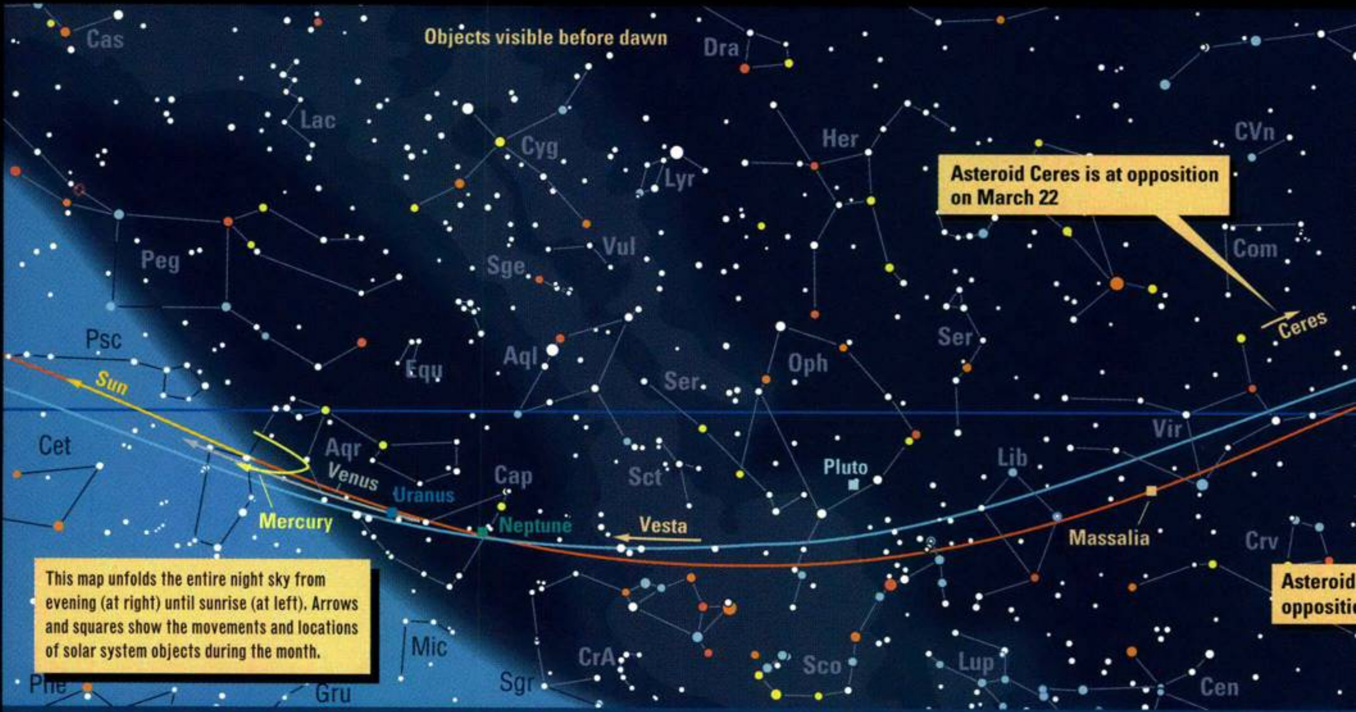
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
South
West
CEPHEUS
CASSIOPEIA
ANDROMEDA
M31
DRACO
URSA MINOR
Polaris
NCP
CAMELOPARDALIS
NGC 869
NGC 884
M33
TRIANGULUM
ARIES
PERSEUS
Algol
M81
M82
Mizar
M51
URSA MAJOR
CANES VENATICI
LYNX
Capella
AURIGA
Pleiades
Saturn
CETUS
M36
M38
M37
LEO MINOR
Castor
GEMINI
M35
M1
Hyades
TAURUS
Aldebaran
Pollux
M44
CANCER
LEO
Denebola
M66
M65
Regulus
ORION
Betelgeuse
Procyon
CANIS MINOR
ERIDANUS
M42
Rigel
SEXTANS
HYDRA
MONOCEROS
LEPUS
Sirius
M47
CANIS MAJOR
M41
PYXIS
Adhara
ANTLIA
PUPPIS
COLUMBA
NGC 2477
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
10:00 P.M. on March 1
9:00 P.M. on March 15
8:00 P.M. on March 31

Planets are shown at midmonth

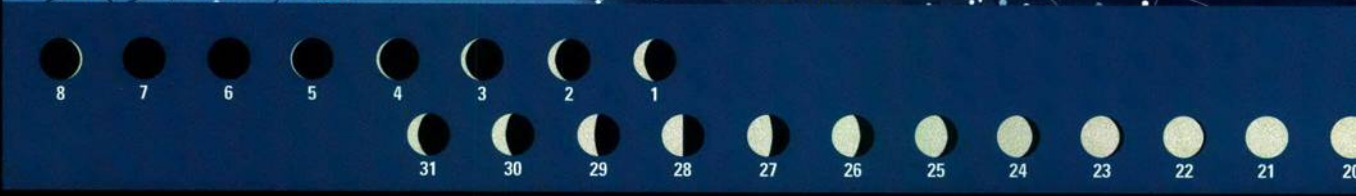
THE PATH OF THE PLANETS


Objects visible before dawn
Cas
Lac
Cyg
Lyr
Dra
Her
CVn
Com
Peg
Sge
Vul
Psc
Sun
Equ
Aql
Ser
Oph
Ser
Ceres
Cet
Aqr
Venus
Uranus
Mercury
Cap
Neptune
Sct
Vesta
Pluto
Lib
Vir
Massalia
Crv
Mic
Sgr
CrA
Sco
Lup
Cen
Phe
Gru

Asteroid Ceres is at opposition on March 22

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

Asteroid
oppositi


8
7
6
5
4
3
2
1
31
30
29
28
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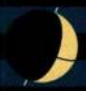
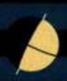
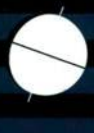
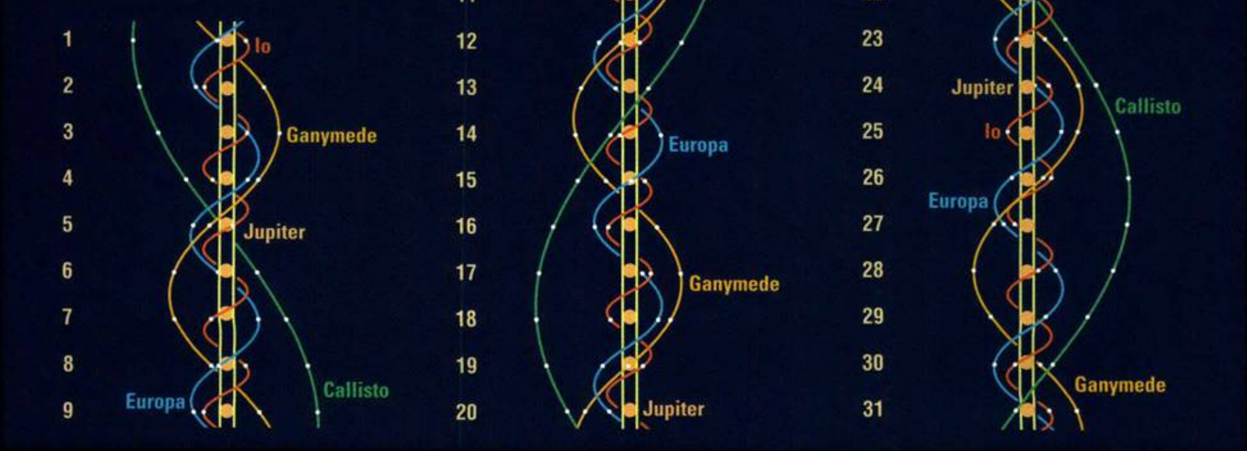
23
22
21

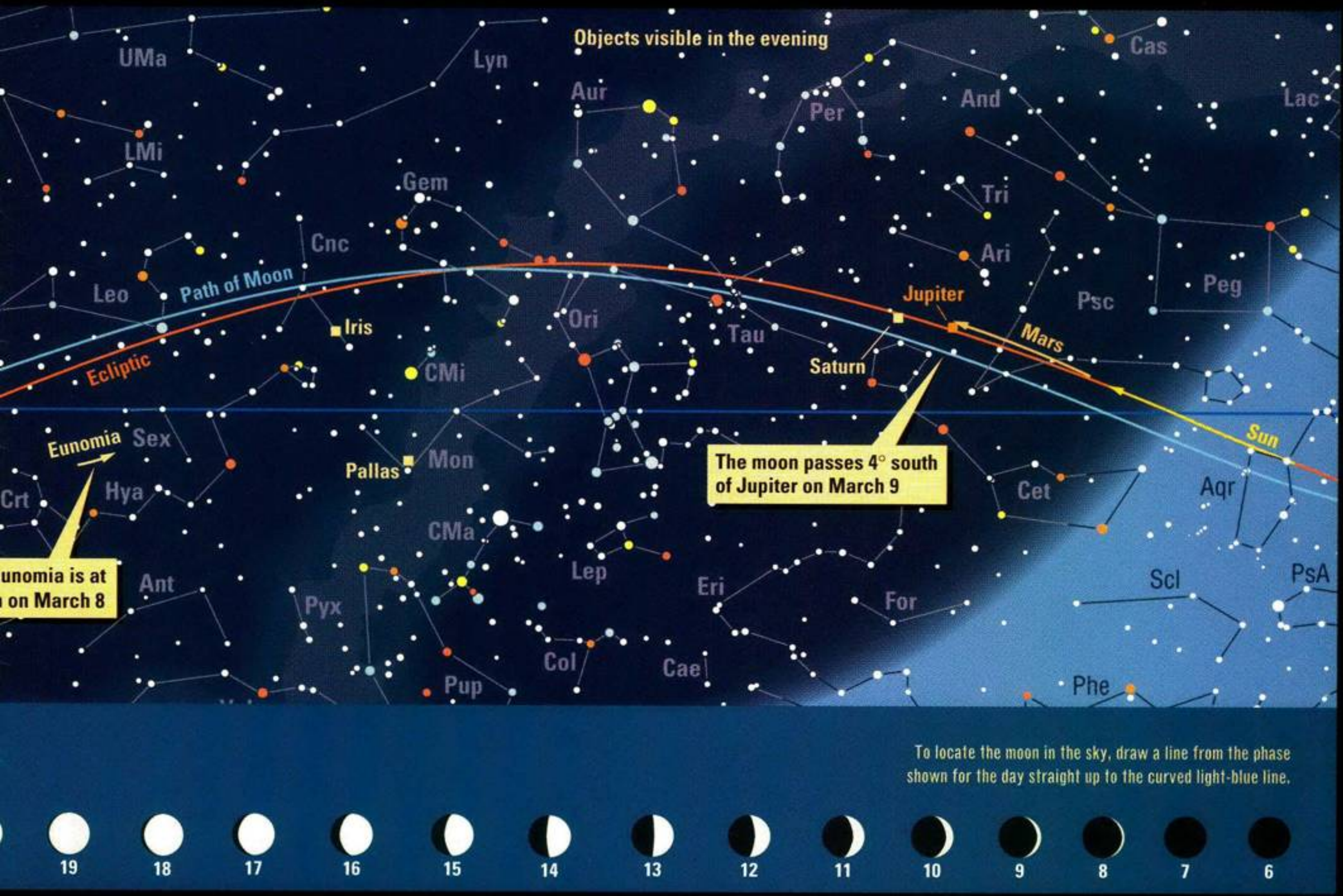




PLANETS	MERCURY	MERCURY	VENUS	MARS	JUP
Date	March 15	March 31	March 15	March 15	Mar
Magnitude	1.1	0.2	–3.9	1.4	–
Angular Size	9.6"	7.3"	10.9"	4.2"	34
Illumination	24%	54%	92%	97%	10
Distance (AU) from Earth	0.701	0.926	1.534	2.241	5.
Distance (AU) from Sun	0.433	0.467	0.728	1.458	4.
Right Ascension (2000.0)	22h17.2m	22h59.7m	22h17.1m	1h29.3m	2h1
Declination (2000.0)	–9°20'	–8°20'	–11°50'	9°13'	12

JUPITER'S MOONS

Dots display positions of Galilean satellites at 10 P.M. EST on date shown. South is at top to match the view in a telescope.

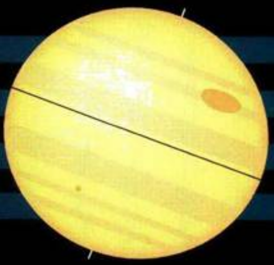



Objects visible in the evening
UMa
Lyn
Aur
Per
And
Cas
Lac
LMi
Gem
Tri
Cnc
Ari
Leo
Path of Moon
Iris
Ori
Tau
Jupiter
Psc
Peg
Mars
Ecliptic
CMi
Saturn
Sun
Eunomia
Sex
Pallas
Mon
Cet
Aqr
Crt
Hya
CMa
Lep
Eri
For
Scl
PsA
Ant
Pyx
Col
Cae
Pup
Phe
19
18
17
16
15
14
13
12
11
10
9
8
7
6

The moon passes 4° south of Jupiter on March 9

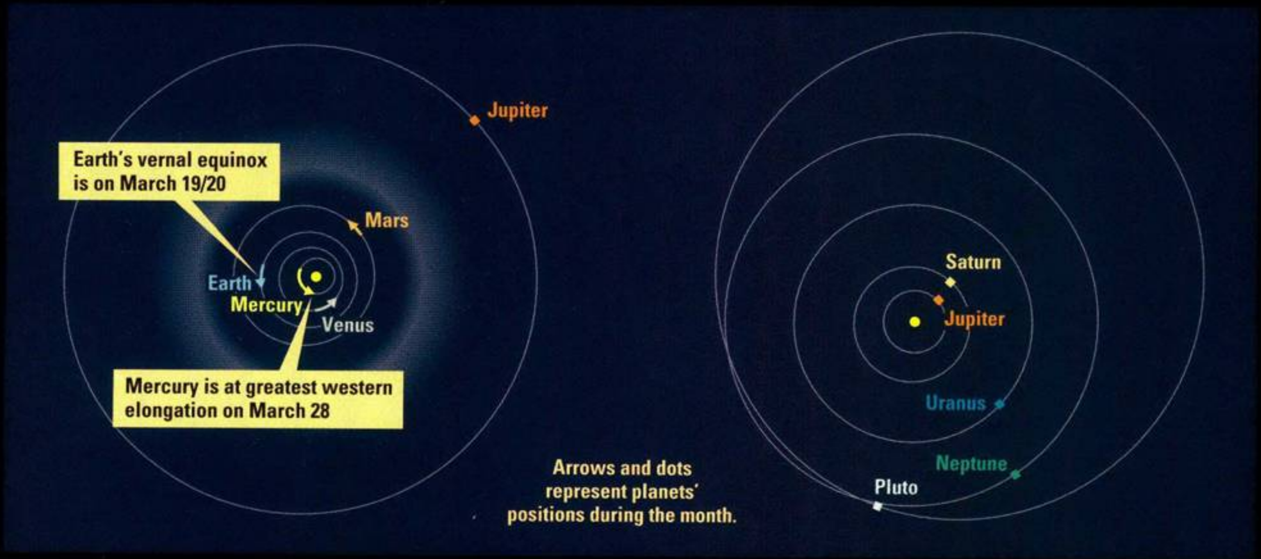
unomia is at
on March 8

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.



TER	SATURN	URANUS	NEPTUNE	PLUTO
n 15	March 15	March 15	March 15	March 15
1	0.3	5.9	8.0	13.8
"	17.0"	3.4"	2.2"	0.1"
%	100%	100%	100%	100%
7	9.790	20.729	30.762	30.030
6	9.168	19.931	30.118	30.246
0m	2h47.5m	21h26.1m	20h32.4m	16h51.6m
6'	13°56'	–15°48'	–18°36'	–11°18'

THE PLANETS IN THEIR ORBITS


Jupiter
Mars
Earth
Mercury
Venus
Saturn
Jupiter
Uranus
Neptune
Pluto

Earth's vernal equinox is on March 19/20

Mercury is at greatest western elongation on March 28

Arrows and dots represent planets' positions during the month.

FIRST VIEWS: A Public Display of Affection

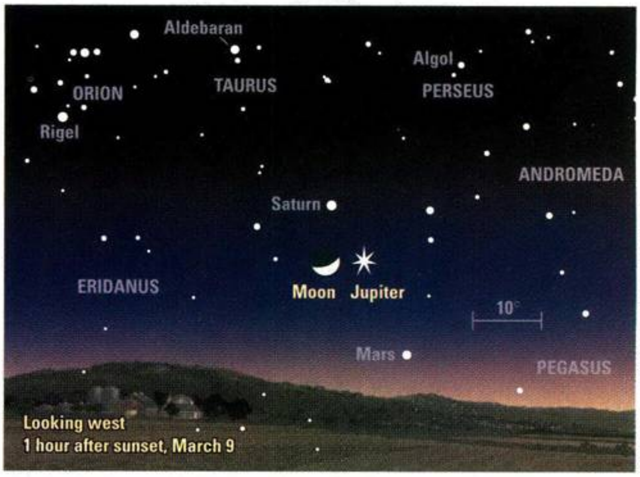
Now's the time to get involved with your local newspaper, TV, and radio media. From the 7th to the 10th, the evening sky is strutting its stuff on a grand scale. Mars, Jupiter, and Saturn all line up nicely with that most beautiful of sights, the crescent moon, which courts each planet, one evening at a time.

Because the event happens midweek, you might want to plan ahead to have a few telescopes out in a public park. On the 7th, the crescent moon should be bathed in delicate earthshine. This phenomenon results from sunlight bouncing off an almost full Earth, up to the moon, then reflecting back to us.

The moon hangs below the line of planets because its orbit is inclined 5° from the average of the solar system. At this point in its orbit it happens to be far on its southbound leg.

Around 45 minutes after sunset, when the twilight colors create a vibrant canvas, this solar system waltz commands a photograph or two. Automatic cameras do a decent job — better still when you can force the exposure one notch shorter than what the light meter suggests.

Encourage bystanders to use binoculars to get a closer look. On the 8th, Mars skims one binocular field of view to the crescent's right. On the 9th Jupiter becomes the moon's partner, and finally, on March 10, Saturn lies off to the right. Next month, more interesting alignments among these three planets await, just before Saturn and Jupiter sink from view. And by this time next year, Jupiter and Saturn will form a tight triangle with the Pleiades when the moon comes to call, and Venus will sparkle as a diamond on the horizon.



Looking west
1 hour after sunset, March 9

All illustrations: *Astronomy*/ Elisabeth Rowan

wobbling motion of Earth known as precession, the First Point of Aries now lies in Pisces. The sun reaches this point at 2:36 A.M. on March 20, marking the beginning of springtime in the Northern Hemisphere and autumn in the Southern Hemisphere.

Ahead of Taurus the Bull and setting with the bright planets in the evening is the constellation Cetus the Whale — dimly visible now as its head leaves the sky scene until later in the year. High in the southwest the winter constellations are gathering, ready for their slide into the twilight zone as the season progresses. Orion and Taurus are well placed for viewing in the early evenings, and passing almost overhead for North American viewers is Gemini the Twins. Lying to the south is the solitary, brilliant star Procyon in Canis Minor the Little Dog. Far to its south reigns the brightest star in the entire heavens, Sirius the Dog Star. Its brightness stems in large part from its closeness to Earth — a mere 8.7 light-years from the sun, making it the sixth closest star to us. The winter stars slide slowly westward each night when viewed at the same time. The stars rise 4 minutes earlier every night, causing an apparent westward shift in the constellations that becomes easily apparent on monthly time scales — amounting to a two-hour difference.

March is guaranteed to come in like a lion this year — at least as far as the constellations are concerned. On March 1, Leo the Lion rises in the east. Taking a springtime star tour in the eastern half of the sky, you'll notice the stars appear decidedly fainter than the setting winter stars. Only three 1st-magnitude jewels appear in the eastern sky during the evening, compared to the eight brilliant gems over in the west. First on the list and high in the southeast, the ruby-red Regulus already stands proud as the heart of the lion (or the period in the backward question mark, if you prefer). The next bright star to show above the east-northeastern horizon is the sparkling citrine of Arcturus lying in Boötes the Herdsman. It rises shortly after 10 P.M. local standard time on March 1 and about two hours earlier by March 31. Roughly 45 minutes later, the icy topaz of Spica in Virgo pops over the eastern horizon, completing the trio of bright stellar treasures in the sky.

The gems in the springtime sky, however, are subtler. The region of Leo, Virgo, and Coma Berenices is decked with galaxies. Many are listed in Messier's catalog of deep-sky objects and can be viewed with a 6-inch scope. Trailing behind Leo later in the evening is a chain of galactic wonders. Your patience in finding them will be rewarded with a bountiful array of distant stellar metropolises.

An interloper in Virgo adds interest to this region of sky. The wanderer is an asteroid — Ceres — the first ever asteroid to be discovered back in 1801 by an Italian astronomer named Giuseppe Piazzi. Many asteroids orbit the sun in the asteroid belt — the region that stretches 2 to 3 AU from the sun between the orbits of Mars and Jupiter. At 580 miles in diameter, Ceres looms larger than all other asteroids and all but the major satellites in the solar system.

Ceres reaches opposition on March 22 at magnitude 6.9, making it an easy binocular object. The difficulty will be identifying which object at 7th-magnitude is the asteroid. Since it moves from night to night, its motion will betray its presence. You can identify Ceres by drawing the stars in the field of view on one night and then again on the following night. Its orbit is inclined 10° to the ecliptic, so its path can wander out of the typical zodiacal constellations, and in mid-month Ceres passes into Coma Berenices. On March 1, Ceres stands 3.5° northwest of Epsilon (ε) Virginis, or Vindamiatrix, a magnitude 2.8 star marking the eastern tip of the "Y" of Virgo. During the spring equinox on March 20, Ceres passes in front of the 11th-magnitude galaxy NGC 4548, often referred to as the lost "M91" in Messier's catalog. However, with the full moon a few degrees away, the galaxy will not be visible, so this event will remain a curiosity only.

As Virgo rises in the east, far across to the northwest Cassiopeia swings low, followed closely by Perseus. Perseus is home to Algol, the famous variable star that undergoes an occultation by a dimmer secondary star every 2.9 days, causing it to dim by a full magnitude in 10 hours. Look for the star at its dimmest on the evening of March 22. Note how bright Algol appears as soon as it is dark. Compare its brightness to a neighboring star, then repeat the following night. Algol will have returned to its normal magnitude 2.1 by March 23.

You can tell what season it is by stepping outside in

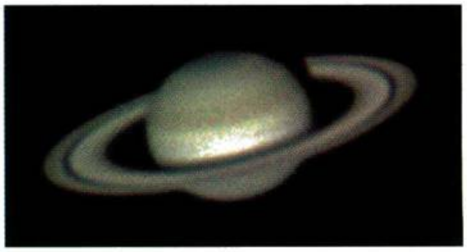
Closing Time for the Gas Giants

Observe Saturn and Jupiter while you can. They continue sinking lower in the sky, where a greater stretch of Earth's atmosphere blurs the view. By next month they will be so low that it will be hard to see details in them. Take advantage of balmy spring nights. They frequently offer steady (but humid) air masses as the warm gulf air wafts northward over cooler land.

Jupiter's cloud belts have been active recently. Some white ovals continue to dominate, while a darker, reddish "barge" has developed in the atmosphere. Saturn's clouds have been less active, but definite, dusky yellow-brown bands are visible. The delicate veil of the inner crepe ring is what gives the equatorial area its deepest hues.

Use as much magnification as the night sky permits. Don't be afraid to push past the old 50x per inch of aperture rule for 3- to 6-inch scopes. Modern, high-quality optics deliver great images. Borrow a Barlow lens if you don't have one yourself.

More information on Jupiter and Saturn can be found at http://www.lpl.arizona.edu/alpo, the web page of the Association of Lunar and Planetary Observers. This group brings novice and experienced amateurs together to share their fascination of solar system objects. When light pollution prohibits so many from observing fainter objects, this branch of astronomy offers a pursuit that can be enjoyed by all.

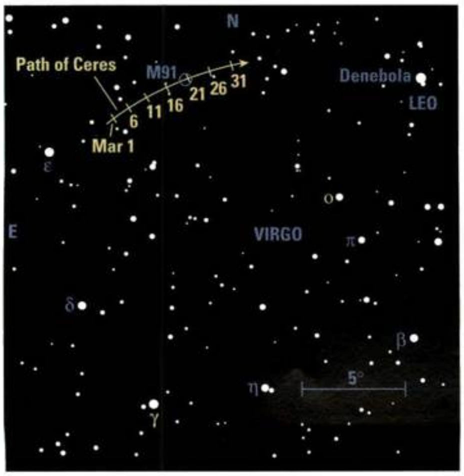


David Hanon

Taking Potshots at Asteroids

Instead of tracking down our quarry this month, we've got traps set for a trio of asteroids that are coming to us. On Saturday night the 18th, two asteroids will be close to modestly bright stars, making them really easy to bag, even from the city with a small scope. You should see obvious motion in an hour or so.

One of the sky's most beautiful double stars, Porrima (Gamma [γ] Virginis), is the first trap. Its pair of almost identical magnitude 3.4 and 3.5 white diamonds is separated by 1.5". Boost the magnification past 100x to get a good look. At 10th magnitude, Asteroid 51 Nemausa shines somewhat fainter than the large saturnian moon Titan. On the 18th, Nemausa slides northeast of Porrima by an apparent distance of two ring-diameters of Saturn, about 90".



On the same night, hop over to Omicron (o) Virginis. This 4.1-magnitude yellow star plays the part of decoy for 52 Europa. Although glowing feebly at magnitude 10.4, Europa (not to be confused with one of Jupiter's satellites) lies an easy 120" to the east.

CCD users and big scope owners can catch the number one asteroid, Ceres, playing a supernova on the 21st. At 7th magnitude, Ceres will overpower the outer halo of 10.8-magnitude NGC 4548, a spiral galaxy sometimes referred to as Messier 91. It's a real pity the almost full moon will be there to bleach out an otherwise notable event. Next month Ceres makes for a pretty easy backyard catch.

A Pyramid in the Sky

Have you ever had a hard time seeing an object, then suddenly something clicks, making it obvious? The zodiacal light is one of those objects — it impersonates the twilight glow after the real twilight has faded. All you really need is your watch and a dark sky free from city light pollution and moonlight.

The zodiacal light consists of a large, soft, pyramidal-shaped glow caused by sunlight scattering back to Earth from microscopic space dust. The tiny particles generally orbit in the plane of the solar system, and so, like the planets, lie along the ecliptic, or zodiac. The top of the pyramid lies about 30° up, one-third of the sky from horizon to overhead — a truly great show.

Scan the western sky in a big, slow swath and you'll be able to see the sky brighten, then fade. The pyramid is often brighter than the winter Milky Way through Cassiopeia and Auriga. Wait until the sun is 18° below the horizon, known as the end of astronomical twilight, and the zodiacal light will appear. At 30° north latitude, this is one hour and 20 minutes after sunset; at 40°N, it's one hour 30 minutes; and at 50°N, it's one hour and 50 minutes after sunset.

Lynn Carroll

What Pleasures Await

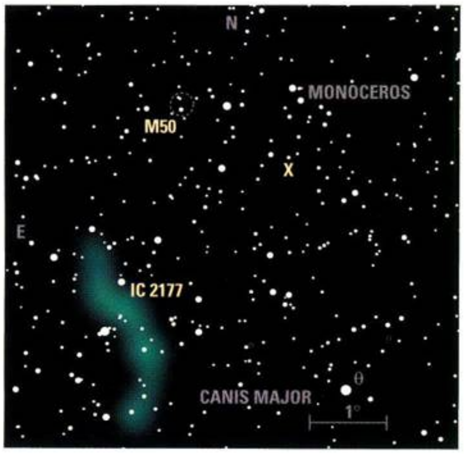
Observers really enjoy scanning the Milky Way — simply pointing their scope outward into the Galaxy and slowly sliding it around. At some point the sky will offer up a surprise. It's like opening a birthday present from the cosmos.

While star-hopping up to M50 (NGC 2323), a splashy open star cluster not far from Sirius, Canadian Randy Pakan landed on a double arc of stars that looks unmistakably like the number three (3). At 15' across, the "3" spans about ¼ to ½ of a low-power field of view.

M50 stands out well in a finderscope. Thanks to its bright stars and dozens of companions, this is a good city object. Just about halfway between Pakan's 3 and M50 lies X Monocerotis, an orange-red drop suspended in the sky. This semi-regular variable has a period of 144 days and deviates between magnitude 6.8 and 10.2.

Back at M50, use your scope at low power to shift two to three fields of view to the southeast, and you may trip across a pretty, almost east-west line of 8th- to 9th-magnitude stars. It doesn't matter that it's just a random grouping of stars laced out into a chain, it's an eye-catching delight nevertheless.

Slide farther south 2° with an 8-inch scope under dark skies and you'll reach a fascinating, complex swirl of bright and dark gas clouds nestled among faint star clusters — the well-known but seldom observed Seagull Nebula (IC 2177). Use the map below to help you star-hop to each of these objects.



the evening and noting how the Big Dipper looks in relation to the horizon. In spring, the Dipper appears to be high in the sky and upside-down. Imagine it pouring water for the springtime flowers. Summer shows the Dipper with its bowl pointed down, poised to take a dip in a cool pond. In autumn the Dipper appears "right-side-up," ready to catch the falling leaves. And in winter the Dipper's handle points downward like an icicle.

This familiar asterism in Ursa Major has not always looked like a Dipper, and its shape will change again in many thousands of years. When looking at the Big Dipper "right-side-up" (or as it appears in autumn), most of the stars are moving together in a direction up and to the left. However, Alkaid, the star at the end of the handle, and Dubhe, the star at the top right corner of the bowl, are moving down and to the right. Future observers will have to rename this asterism when it no longer looks like a dipper.

With the end of winter and the spring equinox, the Big Dipper loops high, reaching almost overhead by midnight. The Dipper carries some fine galaxies along with it, most notably M81 and M82. You can find them most easily by drawing a line from Gamma (γ) through Alpha (α) Ursae Majoris (one of the pointer stars) and extending the line further by 10° — then scan the area for two faint, fuzzy cloud patches — they are quite recognizable in a decent finderscope. M81 is a fine Sb-type spiral galaxy shining at magnitude 8.0. M82 is a galaxy in which a massive amount of star

OBSERVER'S CHALLENGE: Return of the Prodigal Suns

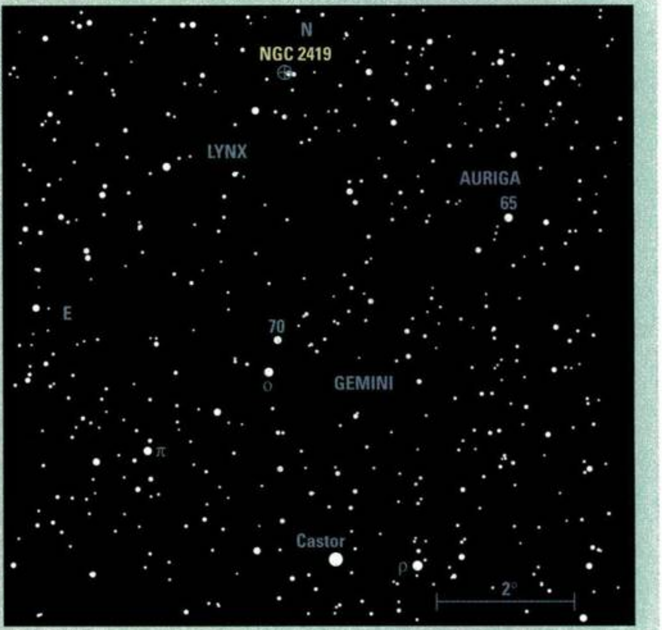
Back in the old days (15 years ago), many astronomers thought a globular cluster in Lynx was masquerading as a Milky Way member but was actually just a passerby. The bright fuzzball cataloged as NGC 2419 was called the "Intergalactic Wanderer."

Discovered in 1788 by William Herschel, NGC 2419 remained an unresolved blob until the early 20th century, when photographs could finally catch the brightest of its 200,000 stars. Astronomers measured their luminosity and deduced that this cluster was as far away as the Magellanic Clouds, some 200,000 light-years out.

This incredible distance was believed to be beyond the gravitational clutches of the Milky Way. Research over the last few decades has shown that not only is the Milky Way larger than we used to think, but there is also a lot of "dark matter" in the fringes of our Galaxy that adds to its mass. This means that NGC 2419 is firmly in the reign of the Milky Way's gravity, not "wandering" near the vacant space between the galaxies.

You can find this distant globular with a 6-inch scope from dark, country skies. The 10.3-magnitude NGC 2419 lies close to the bright stars Castor and Pollux. It's about 7° north of Castor.

Preston Scott Justis



Jovian Juxtapositions

Jupiter's Galilean moons are always in motion. Their breathless cycles are fascinating to watch as they rythmically fall in and out of step, gliding around the hub that is the gas giant.

Occasionally, the moons are doing something a little out of the ordinary. On the evenings of the 10th and 20th, observers in the Western Hemisphere can see Jupiter get all four of its ducks in a row.

In complete contrast, the moons are in close quarters on the 5th. Keep an eye peeled for small, dark shadows cast by the three inner moons. Use the center map page to see when one of them is crossing in front, then look for its shadow about one to two hours later.

Watch to see a satellite or its shadow block one of the zones or belts below in Jupiter's atmosphere. If you observer these events often enough, you may even seen an eclipse over the Great Red Spot.

Careful observers will notice that the moons appear to be out of alignment. Although the moons' orbits lie in a flat plane, that plane is tilted toward Earth, so on the near side the moons are south of Jupiter's center, and on the far side they're north. In another three years, the plane will be edge-on to our line of sight, and we'll witness another exciting series of events where moons eclipse and occult one another.

Don Parker

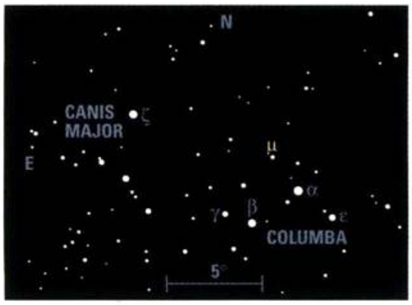
Runaway Stars

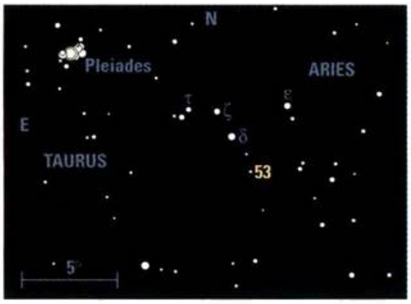
Astronomy offers more than mind-blowing views of Saturn's rings, the glory of sunrise splashing across the basin of the moon's Mare Crisium, or the awesome spectacle of a total eclipse of the sun. It also opens our minds to the weirdness of space, to things utterly inconceivable to the brilliant minds of the past.

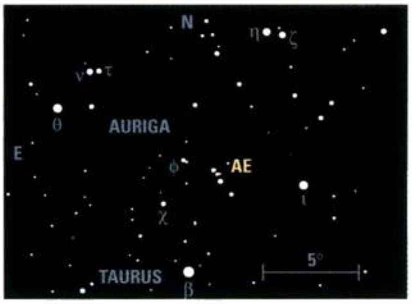
The unmoving stars are an illusion. We're all streaming through space down a celestial avenue. Only because they're so far away do stars seem not to move. Imagine walking across a major street with 50 people. For the most part, the people who start out next to you arrive on the other side with you, but there are always a few in a rush.

Three stars have been caught jaywalking by the astronomical police. Instead of going with the flow, more or less, they are crossing almost at right angles. And to make it more fascinating, if you trace their motion backward, their paths almost cross in the nebulous neighborhood of the Great Orion stellar nursery.

Mu (μ) Columbae, 53 Arietis, and the variable star AE Aurigae are moving through the Milky Way at about 60 miles a second. At 5th and 6th magnitude, they can be seen from a dark-sky site by the naked eye or more easily with a pair of binoculars. Additionally, AE Aurigae is a variable star that appears to illuminate the emission and reflection nebula IC 405. The "Runaway Three" may be slingshot remnants of an exceedingly close stellar encounter or ejections from a violent explosion. It's just one more great story to tell on those nights when you're waiting for the clouds to clear.







formation is taking place, probably as a result of a gravitational interaction with M81. M82 has a high surface brightness, and its pencil-line smudge on the sky is easy to pick out in most scopes.

During the two hours before dawn we get a sneak preview of the summer sky. The summer triangle sits above the eastern horizon by 5 A.M. local time. The brightest star is Vega, halfway up from the horizon to the overhead point in the sky called the zenith. The Northern Cross, also known as Cygnus the Swan, lies above the northeastern horizon, and if it is very clear, you'll see the Milky Way running through it. Low down in the east is Altair, the brightest star in the constellation Aquila the Eagle. Aquila housed the naked-eye nova last December. Follow the horizon around to the south, and you'll find Antares, the M1-type red supergiant star in Scorpius rising in the southeast.

"Beware the Ides of March." This was the warning Julius Caesar, a chief shaper of our present-day calendar, received before he was assassinated by his former friend Brutus and others. The Ides of March originally referred to the time of full moon in the middle of the first month of the Roman year, but now it denotes March 15. This year on the Ides of March and the following day, the two inner planets, **Mercury** and **Venus**, occupy the dawn sky. On March 15 and 16 only 2.1° separates the pair. However, they lie in a bright sky. Venus rises an hour before sunrise and shines at magnitude –3.8, so look for it first, and then try and track down Mercury, which is directly above Venus. Mercury glows at magnitude 0.9 but brightens as the month progresses. Mercury reaches its greatest elongation on March 28, when it stands 28° from the sun and shines at magnitude 0.3, but it remains low in the southeast rising just an hour before the sun.

Through a telescope, Venus exhibits an almost "full" phase — more than 90-percent illuminated — a phase that can only occur with Venus lying on the far side of the sun. Such an observation a thousand years ago was impossible because there were no telescopes. Even so, this simple observation is enough to show that we live in a sun-centered solar system and not an Earth-centered one (as if proof were needed today). In Ptolemy's Earth-centered system it was impossible for Venus to show a full phase, since he had Venus orbiting Earth between us and the sun, displaying only a crescent phase. Mercury, on the other hand, currently displays a crescent phase, presenting an interesting contrast to Venus. Mercury's phase will grow quickly as it approaches greatest elongation, reaching 50-percent illumination by month's end. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

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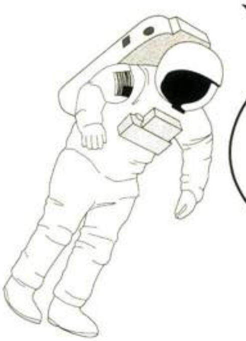

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How to Record the Digital Sky

Run through these tricks of the CCD trade and you'll be capturing digital sky images in no time.

by Gregory Terrance

One night was all it took. I was hooked after my first encounter with CCD imaging. I can still recall the thrill of seeing the images pop onto the computer screen seconds after the camera's shutter closed. Just as impressive was the fact that the images were unguided, 1-minute, deep-sky exposures — a far cry from the 2-hour exposures and film processing that I was used to with astrophotography. While film-based astrophotography and digital astroimaging share similar goals, their differences warrant a close look.

This article, following on the heels of "Capture the Sky on a CCD" (February 2000), provides specific information you'll need to succeed with digital astronomy. Many of the roadblocks to early CCD successes hinge on the fact that digital imaging is radically different from normal photography. Armed with the knowledge of what to expect in an imaging session, however, you'll be well on your way to recording the digital sky.

The Lagoon Nebula (M8) imaged with a 7-inch f/9 refractor, an SBIG ST-8 camera, an AO-7 adaptive optics accessory, and exposures of 21 minutes (red), 21 minutes (green), and 52 minutes (blue). David Hanon

The Cocoon Nebula (IC 5146) imaged with an 8-inch SCT at f/6, SBIG ST-7 camera, and tricolor compositing. William McLaughlin

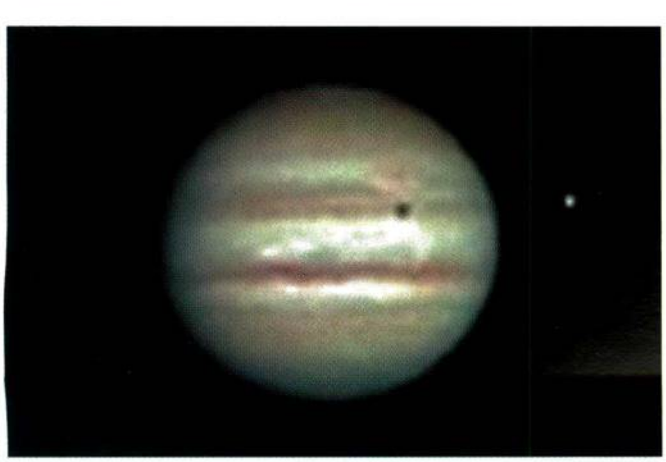
Installing a CCD Camera

Even with limited computer savvy, you should expect to have the image acquisition software installed and the camera hooked up within about 60 minutes. (Be sure to read the manufacturer recommendations prior to installation.) Many cameras use a parallel connection to communicate with the computer; hardware hookup is as simple as connecting the camera and computer with a parallel cable. Other cameras require an interface card (an add-on computer board) that has to be installed inside the computer. This takes a bit longer and requires some extra PC knowledge.

Sometimes, after connecting the hardware, a mismatch occurs between the actual connections and the software settings. In other words, the software "looks" for the camera in the wrong location. This problem often waylays neophytes and causes undo delays. Carefully matching the cable connections to the software settings will ensure that the software detects the CCD camera.

After setting up the equipment, you need to test the system. Your camera's "first light" should be tested on something much closer to home such as the neighborhood kids or a nearby tree. Because a telescope is usually too powerful for initial testing, a camera lens should be placed on the CCD camera head for this procedure. Begin by taking a series of short exposures (1 second or less) with the camera lens set to its highest f/ratio setting (f/32, f/28, etc). If everything is connected and operating properly, you should see an out-of-focus image appear on the computer screen. Continue to expose as you adjust the lens for proper focus. When you get a sharp image, you can be assured that you have a fully operational CCD camera.

When you've passed the testing phase and are ready to take astroimages, you'll quickly discover that a CCD camera may reveal flaws in a telescopic system. Telescopes adequate for visual use may require improvements for CCD imaging. Flimsy focusers, shaky mounts, shifting optics, or poor drive



Jupiter's cloud bands and satellite Io imaged with a 5-inch refractor at f/30 and a Starlight Xpress MX5c camera on July 6, 1998. Todd Gross systems will become a source of frustration and ultimately limit the potential of your images. For more information on CCD-related telescope improvements, see the September 1995 issue.

Digital Growing Pains

Beginners struggle primarily with two aspects of astroimaging: focusing the camera and locating objects on the CCD array. Astroimagers don't have the advantage of instantly seeing focusing and centering adjustments as they look into an eyepiece or camera viewfinder. Instead, an astroimager must wait for images to be downloaded from the CCD camera and can only view the images indirectly, on the computer monitor. This takes some time to get used to.

Begin initial focusing by placing the camera into the telescope's focuser and entering the software's focusing mode (continuous exposures). With exposures set for a second or two, point the telescope at a starfield and adjust the focuser so that the star images visible on the monitor get smaller and tighter. The trick here is to make adjustments only after the image on the screen catches up to your changes in focus (due to download times). I generally wait for two exposure cycles before making another focusing change.

Once sharp star images are formed, exposures should be reduced so that the camera does not overexpose (referred to as "blooming" in CCD vernacular). This simple method of watching, waiting, and adjusting will produce reasonably sharp star images that are good enough for your early imaging sessions. However, if you want to equal the great images seen in the pages of *Astronomy*, you'll have to employ a more rigorous focusing method (see "Eight Steps to Perfect Digital Focusing," p. 92).

Once you're in reasonably good focus, you'll want to center your target for imaging. Because a CCD array has a smaller physical size than a 35mm film "chip," it has a correspondingly smaller field of view. That makes the task of placing objects on the array much more difficult than with traditional astrophotography equipment. The smaller the CCD array, the more daunting the task.

Many methods exist for locating and centering an object on a CCD array, and each has its strengths, weaknesses, and associated price tag. Methods range from visually centering objects using an eyepiece to using telescope mounts that can slew and center objects accurately enough to image a dozen objects per hour. The main advantage to the more costly alternatives is that you don't have to remove the CCD camera from the telescope focuser. This is a time saver that will net more images per hour than using an eyepiece and replacing it with the CCD camera.

An evening of imaging should start with collimating the telescope optics and allowing them to reach ambient temperature. Both steps are critical in getting crisp digital images. Every telescope requires a period of time (usually an hour) for its tube assembly to reach the same temperature as the outside air. Producing CCD images during this time, whether they be of deep-sky objects or planets, is not recommended because the delicate shape of the optics will temporarily deform as the scope reaches thermal equilibrium. A cooldown period is particularly critical for planetary work because even small optical errors are magnified as you enlarge the planet so that it can be imaged. Spend time simply enjoying the sky as the scope cools down.

Improper collimation (optical alignment) is another "image killer." It's important to check and adjust the optics prior to each imaging session; that's the only way to get the most out of your telescope. (Even refractors, which are optically stable, should be occasionally checked.) In addition to collimation and cooldown, I recommended that you locate your telescope away from heat sources such as parking lots, concrete buildings, and rooftops, as they retain heat and emit it back into the surrounding air at night. This effect will destroy local seeing conditions for hours.

HOW TO FIND OBJECTS FOR DIGITAL IMAGING

Locating Method	Pros	Cons
Locate with an eyepiece, replace with CCD camera	Inexpensive Simple operation	Unless the eyepiece and camera come to focus at the same point, you will need to refocus the camera for each new object. Slower than other methods
Flip Mirror System – This device diverts light to an eyepiece or allows it to go straight through to the CCD camera.	Many can be adjusted so that they are parfocal with the camera. Centering and focusing can be accomplished in one step.	Added cost ($200 to $1000) Required focuser in-travel Added weight
Guide-Scope or Separate telescope	Ease of use and setup; can be accurately aligned to the CCD	Added cost ($200 up) Smaller apertures will not resolve dim objects Added weight
Digital Setting Circles or Computer Database	Thousands of objects easily found at the push of a button.	Added cost ($300 or more) Accuracy suffers with lesser mounts (or poor mount polar alignment)
Go-To Mounts	Accurate Fast Efficient	Expensive ($4000 to $10,000 or more)

Deep-Sky Imaging

The key factors for good deep-sky imaging are accurate focus, good tracking, and adequate exposures. That implies a beefy, solid mount for the telescope and a solid focuser to hold the CCD camera. Fortunately, many of today's telescopes have kept pace with CCD imaging and offer designs that are CCD friendly.

Start by achieving good focus. First, coarsely adjust focus as described above. Center a moderately bright star in an eyepiece and then replace the eyepiece with your CCD camera. Adjust the focuser until out-of-focus star images can be seen on the PC monitor. As star images begin to form, reduce the exposures (0.5 to 0.25 second) so the CCD camera doesn't oversaturate or bloom. (Bloomed star images have daggerlike spikes at the ends.) Continue making focusing adjustments until sharp star images appear. If your camera has a zoom function, use it to grab a smaller section of the array surrounding the star. This will dramatically reduce download time and also highlight any focusing errors. Once you've reached the best focus possible, take the following steps to reach perfect focus.

The CCD camera that I use (an IMG 1300) has a software feature that indicates the "maximum pixel" value based on the highest photon count as seen by the CCD. This value increases as focus is approached and drops when the image moves away from sharp focus. (Many camera systems, such as the series made by the Santa Barbara Instrument Group, have similar software settings.) Optimum focus is reached once the value is consistently at it highest. Perfect focus is possible by carefully watching the maximum pixel value as the focuser is adjusted. I've used this simple technique in conjunction with a dial indicator to resolve a focuser's location to 0.001 inch, for excellent results.

An equatorial mount, set to the sidereal rate, is required to take deep-sky images. Unlike with astrophotography, many digital deep-sky exposures are brief enough to avoid guiding completely. Many mounts can accurately track the stars for unguided exposures of 2, 3, or even 5 minutes — long enough to capture hundreds of deep-sky objects. Beyond the 5-minute mark however, star trailing can become troublesome as a mount's right ascension and declination errors become noticeable.

Guiding a telescope corrects for these errors. I manually guide deep-sky exposures of 5 to 10 minutes using a separate guidescope and an illuminated-reticle eyepiece. Manually guiding makes sense for these exposures — setup is easy and the exposure is complete before fatigue sets in. For "deep" digital exposures of 15 minutes and longer, I switch to an auto-guider. Long exposures are tedious to guide manually, and justify a larger investment in setup time.

An autoguider is a CCD camera designed to continually monitor and correct for a mount's tracking errors. Even with experience, setup usually takes 10 minutes or longer. The time is well spent, though: autoguiders are accurate and will guide a telescope for hours. Once it's operational, you're free to take a nap, enjoy the night sky, or get a bite to eat.

But why bother guiding for long exposures if a CCD has the ability to capture deep-sky images in a few minutes? The answer to that question lies in an image's signal-to-noise (S/N) ratio. Longer exposures increase the signal (light from a galaxy, nebula, etc.) as the noise level, inherent in every exposure, is left behind. Long exposures show noticeable improvements in image quality as the S/N ratio increases. If the incoming signal isn't strong enough, the final image will be "noisy" and grainy in appearance. An image's S/N ratio ultimately depends on many factors such as the CCD chip architecture (design), its operating temperature, and the length of the exposure.

EIGHT STEPS TO PERFECT DIGITAL FOCUSING

1. Center a moderately bright star in the field of an eyepiece. For accuracy, use an illuminated-reticle eyepiece.
2. Place the CCD camera into the focuser's drawtube.
3. Adjust the focuser until good star images can be seen through the PC's monitor.
4. Use the camera software to zoom into the area surrounding the star.
5. Reduce exposures so that none of the pixels are saturated.
6. Watch the "maximum pixel" values and adjust the focuser in the direction that consistently shows an increase.
7. Once the maximum pixel value drops, optimum focus has been passed.
8. Move the focuser back to the setting that previously provided the best pixel reading.

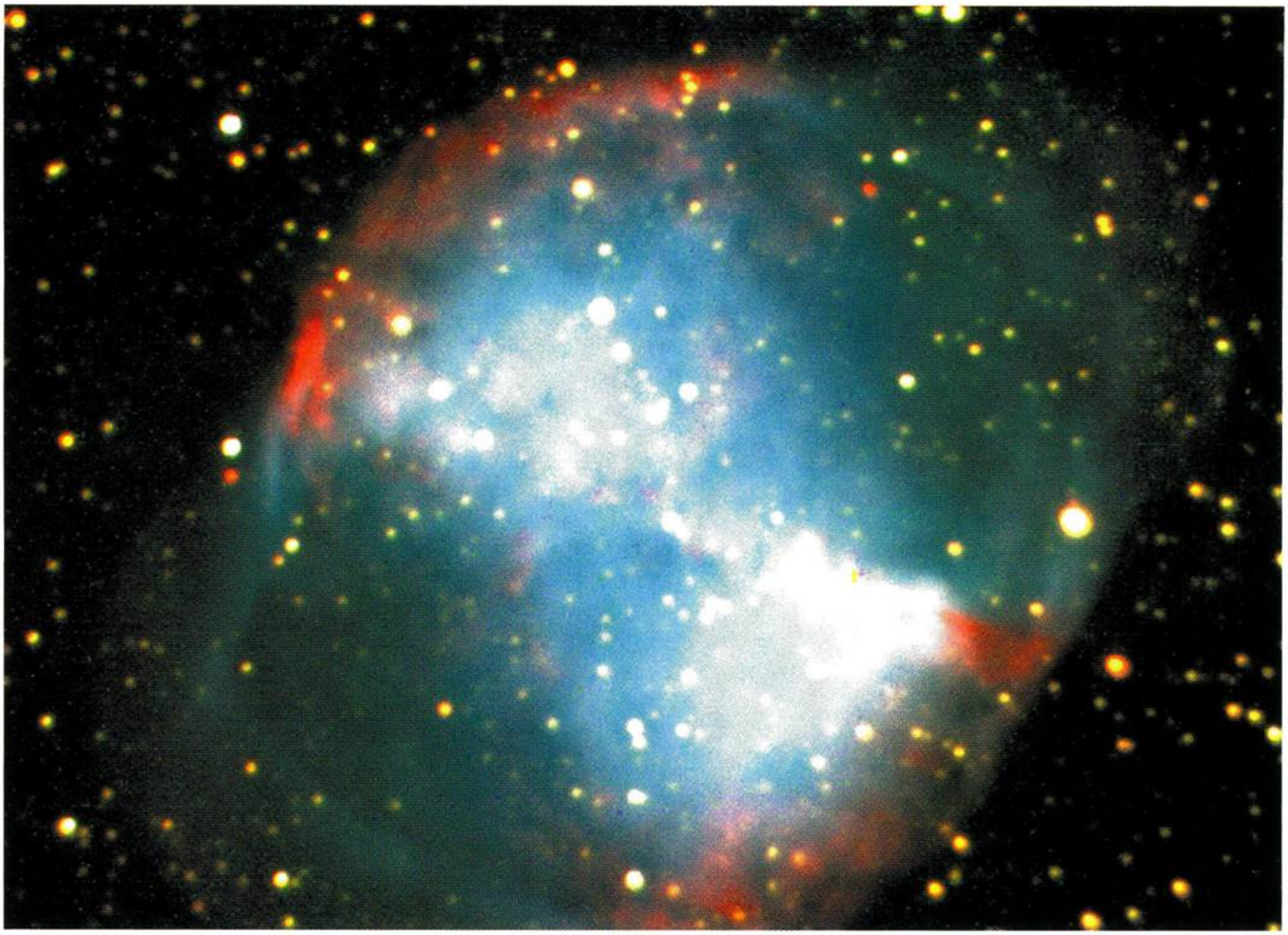
Lunar and Planetary Imaging

The success factors for lunar and planetary imaging are slightly different than those required for deep-sky work. Accurate focus is still paramount, but tracking issues are nearly nonexistent since exposure times are kept brief to minimize atmospheric effects. While most deep-sky imagers try to grab a large section of the sky, lunar and planetary imagers grab small sections of the sky at high power, with eyepiece projection. Finally, a planetary imager must be keenly aware of how steady the evening sky is — something that many deep-sky imagers never consider.

Atmospheric steadiness is a prerequisite for lunar and planetary imaging, without it fine detail is difficult, if not impossible, to record. Before imaging, I check an evening's conditions by observing a planet at moderate power (generally at 150x to 200x). If the views are blurry and difficult to focus, I'll wait until conditions improve before imaging. On the other hand, if there is an abundance of detail visible with very little movement in the eyepiece — that's the time to strap on a CCD camera for planetary imaging.

The planets provide a small target to image, and amateur telescopes need a boost in focal length to properly image them. Increasing a telescope's focal length can be accomplished by eyepiece projection. A camera-to-telescope adapter holds an eyepiece, which in turn projects an enlarged image onto the CCD. The effective focal length of the setup depends on the eyepiece: its distance from the CCD chip and the original telescope focal length.

Fortunately a CCD camera requires much shorter focal



lengths than photography did in the past. The benefits of short focal lengths are short exposures, allowing a CCD camera to capture the planet during brief moments of atmospheric steadiness. In fact, a typical planetary CCD exposure is usually 1/10 that required with film. I normally image Jupiter and Saturn at f/25 with exposures of 1/3 and 1/2 second respectively; Mars requires a longer focal length — typical exposures are 1 second at f/40. Venus is so bright that some type of filtration is needed to image it.

Although longer focal lengths are employed, lunar and planetary focusing techniques are similar to those used for deep-sky imaging. The basic steps are to locate, center, and coarsely adjust focus. Final focus is achieved by using the CCD's maximum pixel values. The trick is to interpret the readings since long focal lengths magnify atmospheric turbulence as well as the subject.

With the planet or lunar crater centered, I place the CCD camera and eyepiece projection system into the focuser and put the software into focus mode. In this mode, images are continually "flashed" on the computer monitor, which makes it a simple matter to adjust and visually focus the camera. I then achieve fine focus as discussed earlier. However, at f/25 to f/40, you can't rely on a single exposure to determine focus; many images will be distorted and fuzzy due to poor seeing while others will be sharp during steady moments. When close to focus, I generally make a small adjustment and watch 10 exposures to see if an improvement occurs. Perseverance is key to success; 10 or 15 minutes are often required to ensure that focus has been achieved.

The Dumbbell Nebula (M27) imaged with a 16-inch SCT at f/6, an SBIG ST-8 camera, and exposures of 20 minutes (red), 30 minutes (green), and 60 minutes (blue). David Healy

Once the camera is focused, the process of exposing, sorting, and saving images begins. A huge advantage of using a CCD camera is the ability to see the images seconds after an exposure. Lunar and planetary imaging is really a process of separating the poor images from the "keepers." Unlike deep-sky imaging, 80 percent to 90 percent of exposures are thrown away, unsaved. Don't let this necessity to toss out images disturb you. You'll soon develop a feel for which images are worth keeping and which are not.

Regardless of the type of astroimaging you pursue, start with a basic approach and refine your techniques to suit your equipment. Although a digital camera is a complex piece of equipment, its power can be realized through simple and effective techniques. While there are many CCD types and designs to choose from, the same principles of operation exist for each. The basic skills of focusing, finding, and exposing can be applied to all. Ultimately, the rewards for attention to detail and continual improvement will be superior digital images. 🅰

Gregory Terrance is a frenetic CCD imager living in New York. This is the second article in a four-part series that describes the whole process of digital astroimaging. Astronomy's *editors invite you to send your best digital images for inclusion in Hot Shots.*

ETXtasy

The new ETX-90EC has built-in motors and an optional Autostar computer system that finds, tracks, and even identifies objects.

By Steve Edberg

Meade Instruments introduced its ETX three years ago. It was a compact, fork-mounted 90mm telescope with a clock drive and legs for tabletop use. At that time, few additional accessories were available from the manufacturer. I reviewed this new telescope enthusiastically, noting its high-quality optics and quick setup, as well as a few minor gripes in the ease-of-observing department (see "Tabletop Star Cruiser," September 1997). In less than a year, after-market manufacturers had gotten into the act by providing a wide range of add-on accessories and refinements to the Meade hardware (see "Make the Most of your Meade ETX," February 1999).

The new ETX-90EC has incorporated some of these accessories and added a few new features into the design, while keeping the same price. The tabletop

ETX and Autostar photos by *Astronomy*: William Zuback

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MEADE
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MODE
GO TO
1
2
3
4
5
6
7
8
9
0
?
AUX
HBX
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AUX

legs are no longer included with the telescope, but this is a small loss that can be recovered as an added-cost accessory.

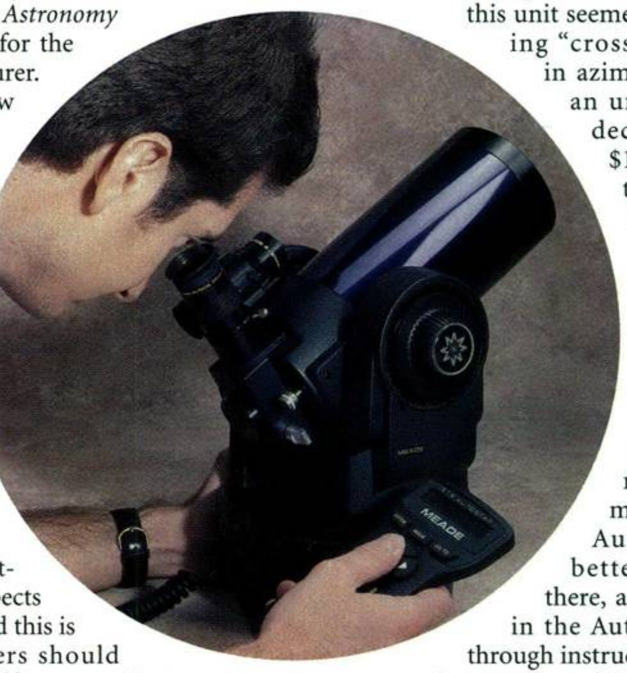
Optically, I get a thrill each time I look through the instrument. The diffraction rings around stars look good and detail on Jupiter is great. The only surprise came during an eclipse expedition to Turkey last August. In some off-center positions, the ETX gave an internal reflection that produced photos with exceptionally bright sources in them (page 97). Yet with a minor change in position, the reflection disappeared. A few ruined photos aside, it was nice to have the electronic controller to make corrections in position.

Something Old, Something New

The old ETX is hard to distinguish from the new. Though the right fork arm is slightly larger, the overall size and shape of the new model is quite similar to that of the old. In twilight or at night, only the drive's power-indicator light and the sound of slewing motors will identify the ETX-90EC from its predecessor. In the light of day, the control panel — with its indicator light, on/off switch, external power receptacle, and remote-control cable receptacles — is in a rectangular area on the side of the cylindrical base of the mount.

One notable change; the base plate has gone from metal to plastic. Access to the eight required AA batteries (five more than before) is now very easy. But for tabletop use, a significant counterweight is gone (not to worry: Meade also offers a counterweight to attach to the tabletop polar leg), and the attachment to a tripod is not as sturdy.

This leads to another concern. *Astronomy* was not sent the accessory tripod for the telescope offered by the manufacturer. It has thumbscrews on its narrow mounting plate to match the two-hole pattern on the base of the drive. For this review, I made a small adapter that allowed me to mount the telescope on an alt-azimuth refractor mount I have. It holds the ETX similar to the way the Meade tripod does. While it wouldn't be a problem when used by most observers in most circumstances, loading the telescope with a piggyback camera or using it for direct photography may, in some positions, flex the base plate enough to influence pointing. One of the most important aspects of a telescope is a sturdy mount, and this is a potential weak point that users should consider. (The home do-it-yourselfer can mitigate this by building a flat plate of ¼" metal or ¾" plywood and carefully affixing it to the tripod and telescope.)



Tripod Tips

If you use a photographic tripod, make sure it has a large mounting surface and minimal flex. Both ¼-20 mounting holes on the bottom of the ETX-90EC are near the edges of the base plate and a rubber footpad is immediately adjacent to one of them. A tripod with a small mounting surface could create uneven loading across the base plate, causing it to flex. With appropriate compensation from the tripod head or legs, the footpad and rim of the cylindrical base may tilt the whole mount slightly.

If a tripod is used to polar align the telescope, be sure to have the telescope's off-center weight over one tripod leg. Otherwise the entire assembly may fall over. To avoid this, buy or build an equatorial wedge. I used a homebuilt wedge (made by Bob Stephens) for the eclipse in Turkey. Though I don't own a Meade wedge, I suspect it would be similar to the Celestron wedge (for an 8-inch telescope) I do own. Both it and the homebuilt wedge support the telescope well.

Using the ETX-90EC is easy. First, plug the hand control box into the telescope base, then turn on the power — reversing this order can damage the electronics. The telescope can be pointed using either the motors or by loosening the locks on the alt-az (R.A.-Dec.) axes, aiming, and then tightening the locks. I recommend this order of operation because the telescope does a self-check when it's first turned on. If the telescope is aimed before the electronics are turned on, the pointing will be off at the completion of the self-check.

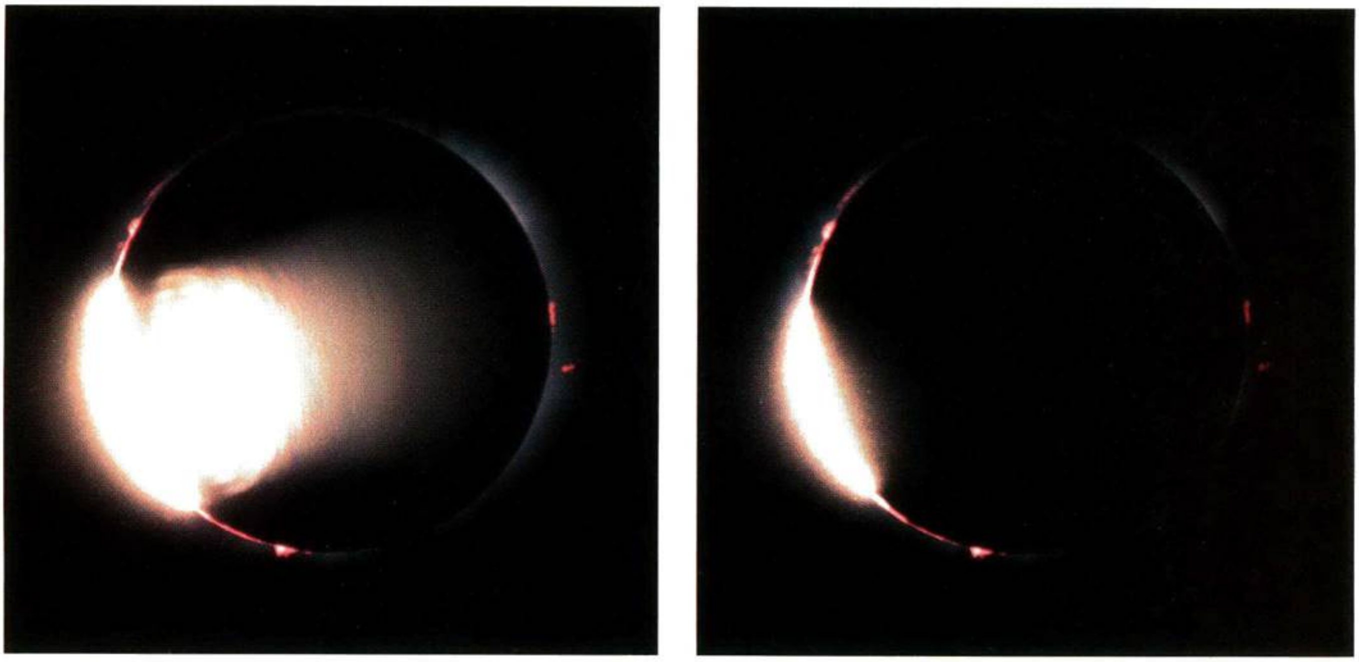
Autostar Automation

With the included electronic remote control, the ETX must be continuously driven in altitude and azimuth to track an object in the sky, but setting it up for equatorial use is easy. Meade provides directions in the manual.

The controller can be adjusted in software (use the "mode" key) or hardware (take out a screw) for use in either alt-az or equatorial mode. The one shipped with this unit seemed to suffer a bit of disconcerting "crosstalk." Making a correction in azimuth/right ascension included an unwanted change in altitude/declination. For an additional $149, an observer can purchase the Autostar computerized hand control.

The Autostar turns the ETX-90EC into the near equivalent of a Meade LX200. The unit is about twice the size of the regular remote control, but smaller, lighter, and rounder than the LX200 controller. It's important to read the small instruction manual that comes with the Autostar. Though it could be better organized, the basics are there, and what isn't in the manual is in the Autostar's help menu or scroll-through instructions.

Getting started is easy. Begin by mounting the telescope on a tripod, level it so the azimuth axis is vertical (use a circular spirit level), set the home position by hand, plug in the Autostar, and turn on the power (remember, the order is important to prevent damage to the electronics). Once on, Autostar's setup instructions will scroll across the screen. Push the Mode button to make the initial settings (some of which are only entered during the first use, provided you observe at the same location). After the date, time, and location are entered, Autostar searches its database for two setup stars. It moves the telescope to the first and asks you to center the star in the field of view. Then it finds the



Internal reflections marred the total solar eclipse image on the left. Slightly repositioning the ETX eliminated this problem. Steve Edberg

second, you center it, Autostar does a quick computation, and you're ready to go. Sometimes the system chooses stars that are named but not widely known. Have an atlas on hand or you'll have to pick the brightest star and assume it's the one Autostar meant to find.

To test Autostar's accuracy, I set up the telescope one afternoon with the sun high in the southwest. I couldn't see the stars to center them but went ahead and pushed "enter" after Autostar had found them. Once the procedure was complete, I went off to find Altair (couldn't see it), Deneb (saw it passing through the main telescope's field of view, but couldn't find it when the telescope stopped moving), and Vega (couldn't find it). The experiment was interesting and characteristic of some of my night experiences. Even with well-centered setup stars and careful leveling, Autostar sometimes missed the target. If I knew where the object was supposed to be, I could make a correction, but someone unfamiliar with the sky won't have that experience and won't know where to look. One thing in Autostar's favor, however, is that it will accept new inputs to refine its pointing algorithm, and it does have a high precision mode that allows observers to help the system find an object.

With the setup complete, you can start selecting objects, take a guided tour, or identify an object you've not seen before. Autostar's extensive catalogs include stars, deep-sky objects (as listed in several catalogs or by category), black holes, planets, and many others. While experimenting with the catalogs, I had two experiences I can't explain. In both (one in alt-az mode, the other in polar mode), Autostar seemed to "lose lock" on itself. Once it told me that a star I wanted to go to, one it had already used for setup, was below the horizon. Then I deliberately asked it to go to another object I knew was below the horizon, and Autostar dutifully motored the telescope to a point on my backyard lawn. These were the only oddities I experienced. On all other occasions, the telescope would get near the target in a low-power field of view, I would correct, and then it would track that object beautifully.

The list of targets in Autostar's database is quite extensive (14,000 objects), but that's not all. Autostar also has utilities for calculating astronomical events such as sunrise/set, moonrise/set and phases, eclipses, and others too numerous to list. And it has telescope utilities and conveniences that make life easier. Clearly, a lot of thought went into the software's design, and updates can be gleaned from Meade's website.

The Meade ETX-90EC with Autostar is a great combination for beginning astronomers and experienced users. The telescope stands alone well, but with Autostar an observer will be more efficient in scanning the sky. Users, especially beginners, should remember that they still need to learn the sky and read star charts. Such knowledge is necessary to make corrections that "train" the computer. After all, Autostar is not as smart as the mind that is both telling it what to do and contemplating the magnificence it presents.

Steve Edberg is a long-time star-hopper being dragged kicking and screaming into the 21st century. He is Executive Director of the Riverside Telescope Makers Conference (www.rtmc-inc.org).

The ETX with AUTOSTAR

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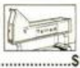

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Size of the Universe, Moons of Mars

Q: If the universe is 12 billion years old, does that mean it is 12 billion light-years in radius?
— Chris Finlay, Edmonton, Alberta, Canada

The faintest blips in this Hubble deep field are among the most distant objects ever seen.

Robert Williams (STScI), the HDF-South Team, and NASA

A: No. If the universe's radius in light-years was the same as its age, that would imply that the universe is expanding at the speed of light. But in reality, the universe's expansion rate changes with time because of the influence of gravity, and possibly a cosmological constant that causes the expansion to accelerate (see "An Inconstant Constant," page 54).

In addition, many astronomers and physicists think the universe experienced a fleeting period moments after the Big Bang when it expanded much faster than the speed of light. During this so-called inflationary epoch, the universe might have expanded so fast that today's universe is hundreds of billions of light-years (or larger) in radius. But since the end of the inflationary epoch, the universe has been expanding much slower than the speed of light. Because of all the uncertainties about the universe's past expansion rate, astronomers don't know the universe's physical radius.

The observed radius of the universe, however, is about 12 billion light-years if the universe is about 12 billion years old and if inflation actually happened. That's because we couldn't see an object whose light takes more than 12 billion years to get here. But even this is misleading, because an object whose light has taken 12 billion years to get here was much closer than 12 billion light-years when it emitted the light and is much farther away now. — *Robert Naeye, associate editor*

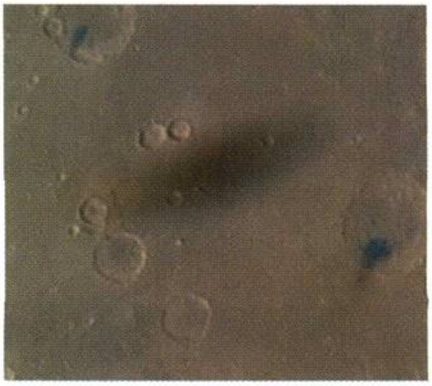
Q: From the surface of Mars, would either of the planet's two moons be visible to the naked eye?
— Lee Pickett, Olympia, Washington

A: The appearance of the two moons in the martian sky is very different from the appearance of Earth's moon in our sky. Some artistic representations assume that "moon" means a big, round disk in the sky, like our moon. But Deimos, Mars's outer moon, is so small and far from Mars that it would look like a bright star drifting very slowly among the background stars.

Phobos, the inner and larger moon of Mars, is also very small (only 17 miles across at its widest point). But Phobos is much closer to Mars. As a result, it would appear about one-third the angular size of Earth's moon in our sky. It is not round so it would have a visibly lumpy shape. Because its surface reflectivity is very low — a blackish color — and sunlight at Mars's distance is dimmer to start with, it would be much dimmer than our moon. Phobos moves almost directly over the equator. Like artificial satellites moving quickly around Earth in low-Earth orbit, Phobos would be seen at dusk and dawn rising not in the east, but in the west, drifting eastward across the sky in a few minutes, and setting in the east. Because of its tight equatorial orbit, it is never visible from the north and south pole.

Future Mars explorers will be disappointed to learn that Mars's two diminutive moons aren't large enough to block the sun's entire disk. As a result, there are no total solar eclipses on Mars. — *William K. Hartmann, Planetary Science Institute; Dr. Hartmann's website is www.psi.edu/hartmann/index.html*

Mars Global Surveyor captures the shadow of Phobos on Mars. Malin Space Science Systems/NASA



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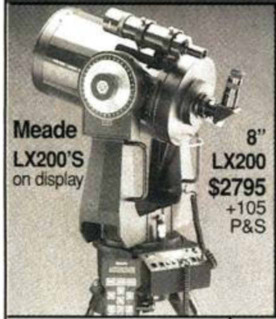

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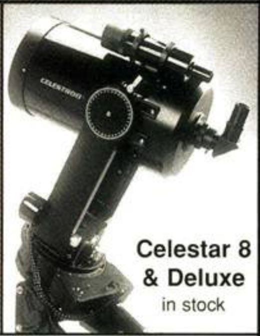

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Harrison Music Corporation, 3808 Riverside Drive, Suite 502, Burbank, CA 91505; phone, (818) 238-9343; fax, (818) 238-9749; website, http://www.spacesongs.com. Space Songs: *$14.99.*

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The Earth

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A New View

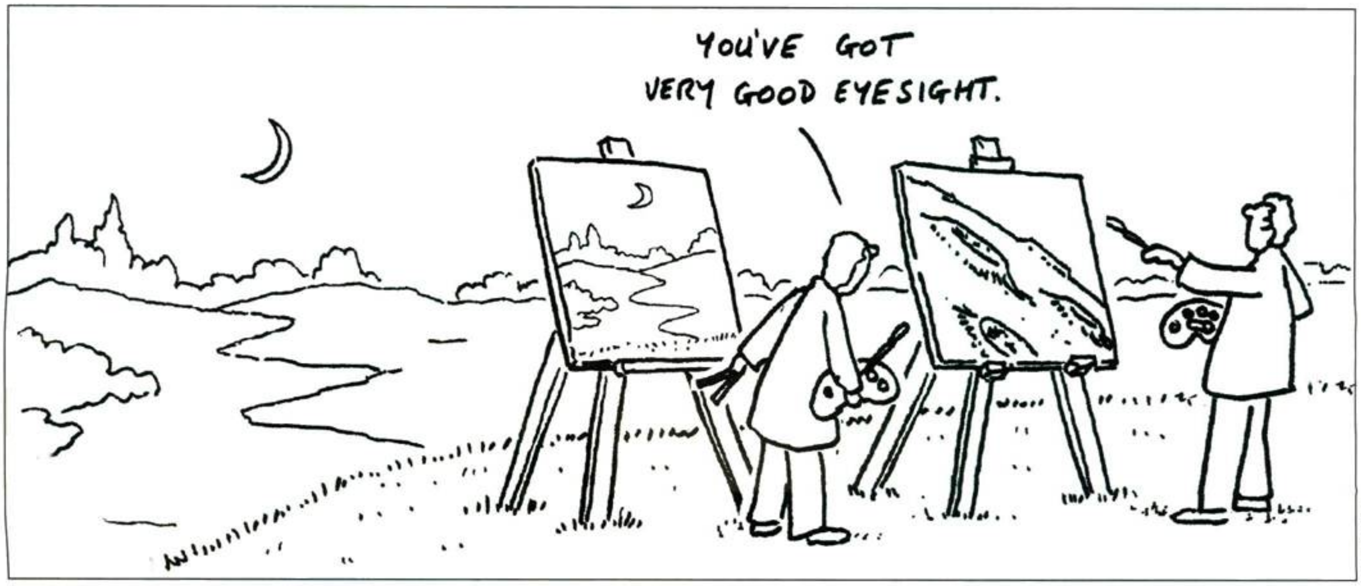
▶ Tele Vue Optics of Suffern, New York, has added an 18mm model to its line of long eye-relief Radian eyepieces. Eyeglass wearers will enjoy the standard 20mm eye relief and a 60° field of view.

Radians feature a click-stop adjustable housing with rubber grip ring, fold-down eyeguard, and a snap-in pupil guide. Their optics include the latest high-index glasses in six or seven element configurations. Radians are compact, relatively light weight, parfocal, and can be used with Tele Vue Barlows or Powermates. The addition of an 18mm eyepiece brings the selection of Radian focal lengths to nine. They include 14mm, 12mm, 10mm, 8mm, 6mm, 5mm, 4mm, and 3mm models.

Tele Vue Optics, 100 Route 59, Suffern, NY 10901; phone (914) 357-9522; website, http://www.televue.com. Radian Eyepieces: *$295 (3mm-18mm).*

The APO-Eater

▶ The resurgence of high-resolution, high-contrast planetary and double-star observing has prompted Starsplitter Telescopes to develop a long-focus Newtonian. Dubbed the APO-Eater, the new design features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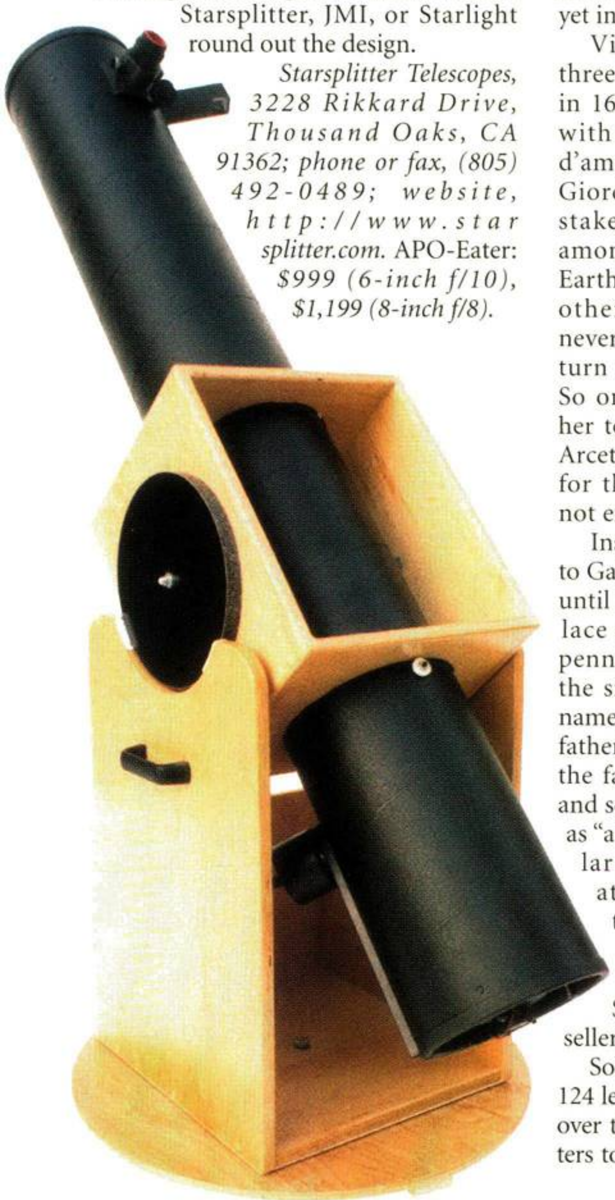
Chris Madden

Starsplitter optics (1/10 wave) or, with an added cost, Zambuto optics (1/20 wave). The primary mirror rests in a nine-point, cast-aluminum cell, while the secondary mirror is held in place by a ProtoStar diagonal.

The standard telescope mount is constructed of Appleply plywood with virgin Teflon bearings and Ebony Star running surfaces. The tube assembly rotates in the mount on four nylon rollers to allow repositioning of the eyepiece for comfortable viewing. Another convenient feature is an adjustable cradle assembly that permits the user to rebalance the telescope when heavy eyepieces or finderscopes are added. Tube baffling and low-profile focusers from Starsplitter, JMI, or Starlight round out the design.

Starsplitter Telescopes, 3228 Rikkard Drive, Thousand Oaks, CA 91362; phone or fax, (805) 492-0489; website, http://www.starsplitter.com. APO-Eater: $999 (6-inch f/10), $1,199 (8-inch f/8).



BOOKS

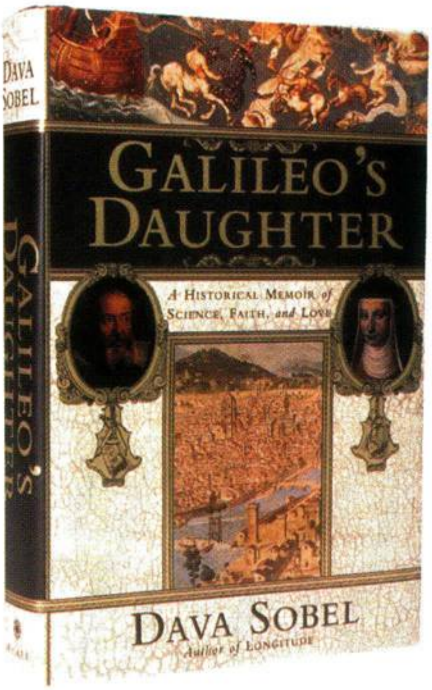
Galileo's Daughter

Dava Sobel, 420 pages, Walker and Company, New York, 1999; ISBN 0-8027-1343-2; hardcover, $27.

▶ The remains of Galileo Galilei lay entombed in the magnificent Church of Santa Croce, in Florence, Italy. Here inscriptions read, "He gave his all to geometry, astronomy and philosophy," and "No others of his time were comparable." His daughter Virginia, however, is not mentioned. "But still she is there," writes Dava Sobel in her new book *Galileo's Daughter*. In death as in life, Virginia remains a constant yet invisible companion.

Virginia, the oldest of Galileo's three illegitimate children, was born in 1600 to Marina Gamba of Venice, with whom Galileo had an affaire d'amour. Ironically, Dominican friar Giordano Bruno was burned at the stake in Rome that same year for, among other heresies, insisting that Earth traveled around the sun like the other planets. Regardless, Galileo never wed Virginia's mother, which in turn made Virginia unmarriageable. So once she turned 13, Galileo took her to the Convent of San Matteo in Arcetri. Here she remained cloistered for the rest of her life. But this did not end their communication.

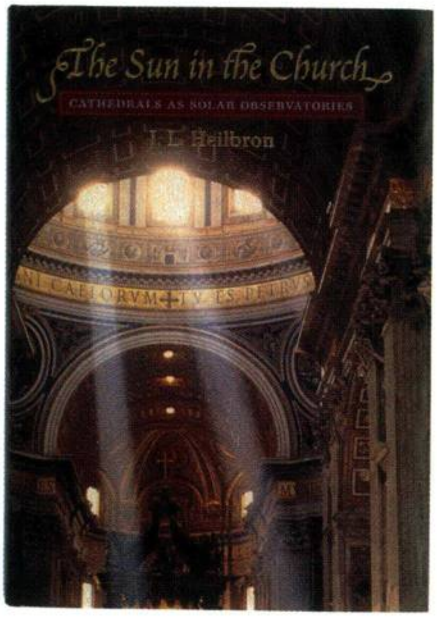
Instead, Virginia remained devoted to Galileo "as though to a patron saint" until her death in 1634. She wove his lace collars, baked him cakes, and penned his writings. Upon entering the sisterhood she even adopted the name Suor Maria Celeste to honor her father's love of stars. Galileo returned the favors, sending her money, food, and sewing materials. He described her as "a woman of exquisite mind, singular goodness, and most tenderly attached to me." So in the end, theirs is not a bitter tale of rejection or abuse but "a love story, a tragedy, and a mystery," writes Sobel, author of the 1995 best-seller *Longitude*.



Sobel found this story in a group of 124 letters that Virginia wrote to Galileo over the course of her life (Galileo's letters to Virginia have never been found). These letters, which were carefully translated by Sobel herself, portray the harsh daily life of a 17th-century convent — a place ridden with poverty, disease, and mental illness. They also go far to modify "the personality and conflict of a mythic figure, whose clash with the Catholic doctrine continues to define the schism between science and religion," Sobel writes. The Galileo of Suor Maria Celeste's letters was not, as popular lore has it, a renegade scientist "who scoffed at the Bible and drew fire from a Church blind to reason." Instead, her Galileo was a devout Catholic who believed in the power of prayer and who always tried to reconcile his duty as a scientist with his religion.

Sobel further embroiders this notion with insightful commentary and forgotten bits of history. She reminds us, for example, that Galileo was happy to submit his writings to the Holy Office for approval — and he sometimes dedicated text to influential members. He was well liked and protected by more than one Cardinal, even after he was condemned for teaching the sun-centered theory of Copernicus. He was also friendly with Pope Urban, who oversaw Galileo's demise, during the early days of his powerful rule.

In fact, the strength and focus of this book is Sobel's retelling of Galileo's story. For while his biography has been written many times, this arduously researched narrative works hard to set the record straight. It takes readers behind the scenes, into his workshop, home, and conversations, to eavesdrop on important events. And though the narrative may slow at times to accommodate a plethora of original documents and quotes, aficionados will delight in the florid, sometimes comical, quality of authentic language. Indeed, *Galileo's Daughter*, like Galileo's telescope, provides fresh perspective on an endlessly fascinating subject. — *Beth Livermore, contributing editor*

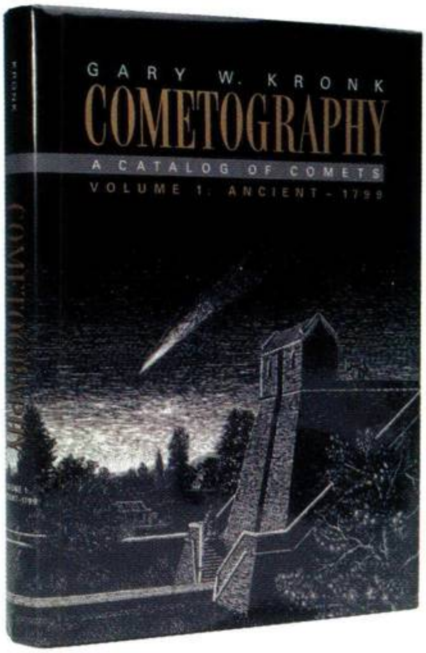


The Sun in the Church: Cathedrals as Solar Observatories

J. L. Heilbron, 366 pages, Harvard University Press, Cambridge, Mass., 1999; ISBN 0-674-85433-0; hardcover, $35.

▶ Drawing upon his encyclopedic knowledge and dry wit, science historian J. L. Heilbron argues convincingly, and entertainingly, that despite its condemnation of Galileo for championing the heliocentric theory of the solar system, the Catholic Church was perhaps the strongest supporter of astronomy throughout the 17th and 18th centuries. From 1650 to 1750, the Church invested vast amounts of money in the construction of cathedrals that doubled as solar observatories. The Church also hired the best astronomers of the day to work in them. Although this massive project accomplished its stated goal of firmly establishing the date for Easter, it also provided the detailed picture of the sun's seasonal motion that ultimately vindicated Galileo.

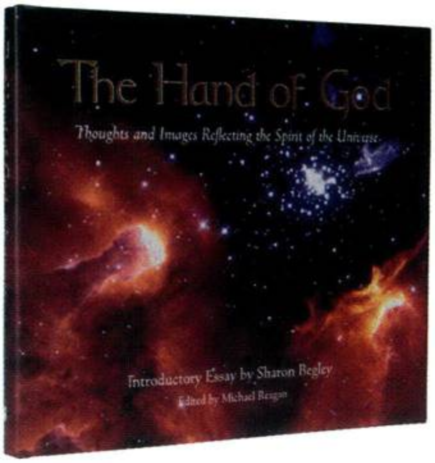
Even though he doesn't skimp on the technical details, Heilbron's deft touch and sly sense of humor enliven this tale of political intrigue, religious belief, and scientific debate. — *Mark Sincell*



Cometography: A Catalog of Comets, Volume 1: Ancient – 1799

Gary W. Kronk, 563 pages, Cambridge University Press, New York, 1999; ISBN 0-521-58504-X; hardcover, $90.

▶ This is the first in a series of four sequential volumes that will serve as the ultimate reference guide for comet lovers. In *Volume 1*, comet authority Gary Kronk lists comets observed in a wide variety of cultures from 674 B.C. to A.D. 1799. He includes references to original sources and uses the most reliable data to determine the key orbital parameters for many of the comets. Historical information is included to help the reader better understand how comet apparitions may have influenced various cultures. *Volume 2* will be published in late 2000 or early 2001.


The Hand of God
Thoughts and Images Reflecting the Spirit of the Universe
Introductory Essay by Sharon Begley
Edited by Michael Reagan

The Hand of God

Michael Reagan, ed., 160 pages, Andrews McMeel Publishing, Kansas City, Missouri, 1999; ISBN 0-7407-0343-4; hardcover, $24.95.

▶ Despite its title, this book will appeal to religious and nonreligious people alike. *The Hand of God* is essentially a compilation of the most beautiful astrophotos ever taken. The 100 or so images are from the Hubble Space Telescope, Europe's Very Large Telescope, the Anglo-Australian Observatory, NASA spacecraft, amateur astronomers, and many other sources. A short quote and a caption accompany each photo. The quotes are from scientists such as Albert Einstein and Stephen Hawking, philosophers such as Johann Wolfgang von Goethe and Søren Kierkegaard, writers such as Mark Twain and Timothy Ferris, theologians, poets, and artists. *Newsweek* magazine science writer Sharon Begley contributes an introductory essay.

God's Equation: Einstein, Relativity, and the Expanding Universe

Amir D. Aczel, 236 pages, Four Walls Eight Windows, New York, 1999; ISBN 1-56858-137-8; hardcover, $22.

▶ Amir Aczel, author of *Fermat's Last Theorem*, has produced another work about mathematics and a man. In easy-to-read prose, he renews the subject of Albert Einstein and his famous "blunder." The story tells us that Einstein's blunder — the cosmological constant — returns not to solve the mystery of a steady-state universe but to understand "strange energy" and the nonstop expansion of our universe. With newly translated letters, background on other key scientific players, and the context of Einstein's time period, the story makes for an entertaining and educational read.

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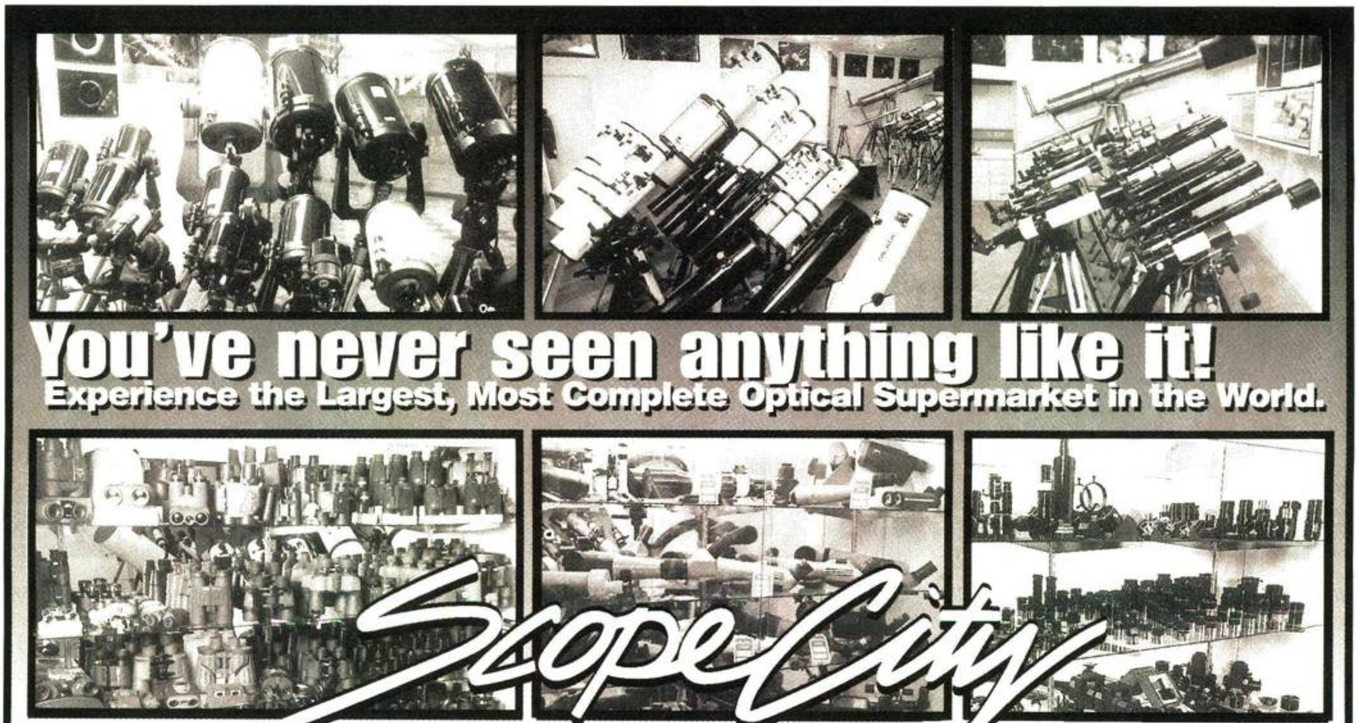
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BYTES

Deep Space CCD Atlas

Those familiar with the *Deep Space CCD Atlas North* and *Deep Space CCD Atlas South* will delight in the release of a CD-ROM version of these popular observing aids.

The original print *CCD Atlas* was the brainchild of John C. Vickers. In the early 1990s, he spent nearly two years gathering images of galaxies and nebulae with a computer-driven 14-inch Schmidt-Cassegrain telescope. With digital photos in hand, he published the *Deep Space CCD Atlas North*. Its popularity spurred the publication of a southern sky version. Vickers's partner in this venture, New Zealander Alex Wassilieff, used his 14-inch Newtonian to gather the images.

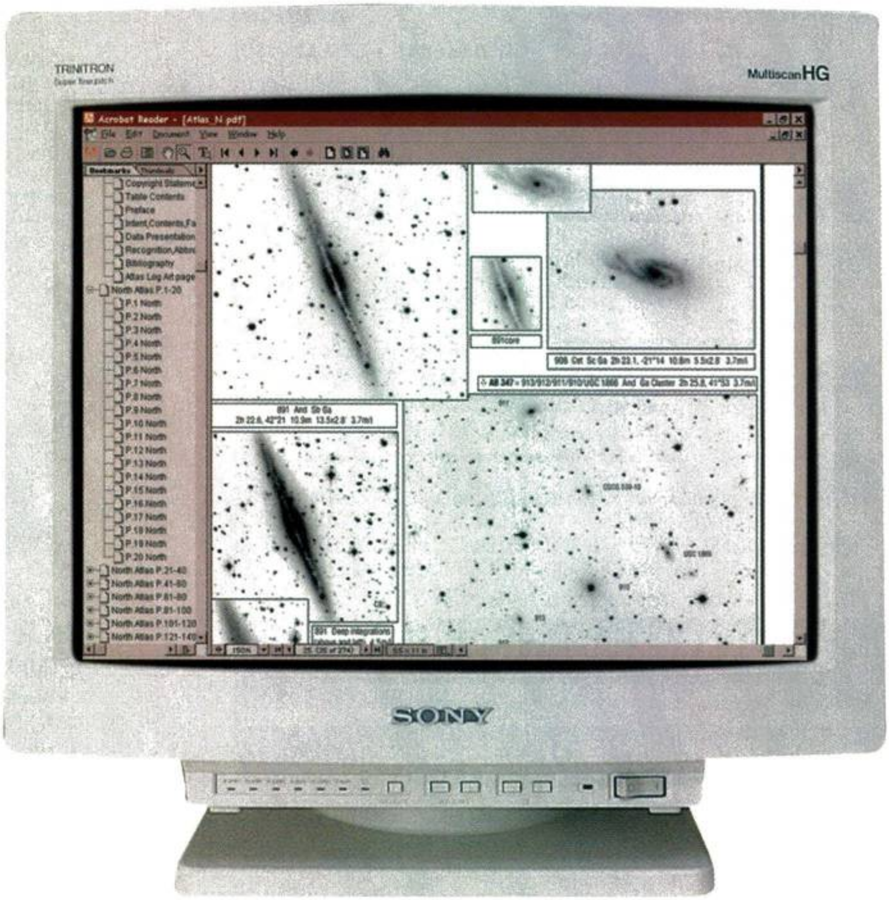
Today, the recently updated north atlas holds some 2,500 CCD images of objects that sit between the North Celestial Pole to 30° below the celestial equator. The south atlas has also undergone a "major tune-up." The imagery and presentation have been improved and roughly 1,600 images from the South Celestial Pole to 30° above the celestial equator, overlapping the north atlas, are included.

The CD-ROM holds the updated versions of both the north and south atlases, as well as a South Addendum of 500 objects. They are presented in Adobe Acrobat's Portable Document Format (PDF), which preserves the print version's original appearance.

The images are organized by right ascension. Information such as the object's class, catalog designation, angular size, and brightness are all held in a text box that accompanies each photo. Image scale in arcminutes per inch is also included.

Deep-sky observers will find this atlas invaluable. Its photographic field of view guides you to the features you hope to see.

Back River Observatory, P.O. Box 1292, Duxbury, MA 02331; phone, (781) 934-6909; e-mail, vickers@gis.net; website, http://www.gis.net/~vickers/BROpg.html. Deep Space CCD Atlas North and South CD-ROM: *$37 (plus shipping and handling).*



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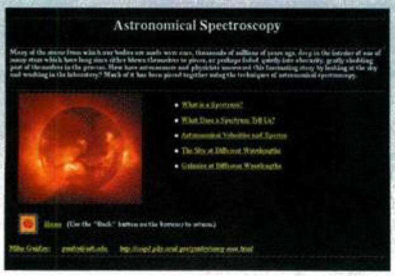
http://www.achilles.net/~jtalbot/spectra/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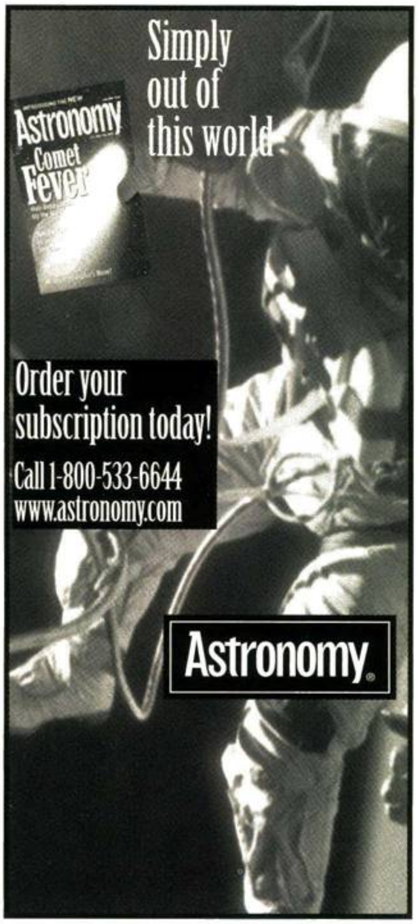

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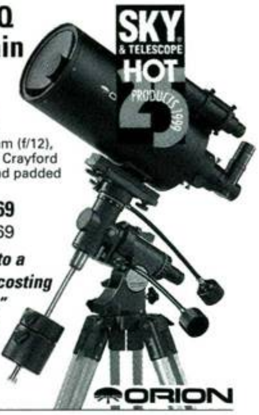

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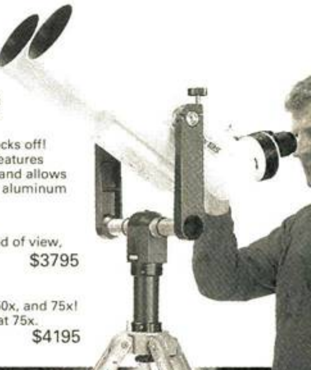

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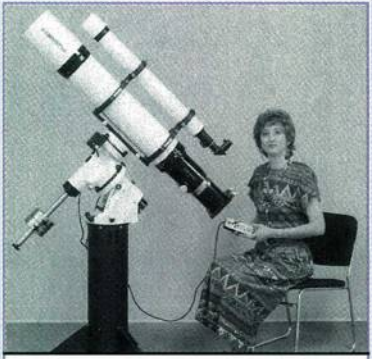

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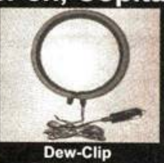

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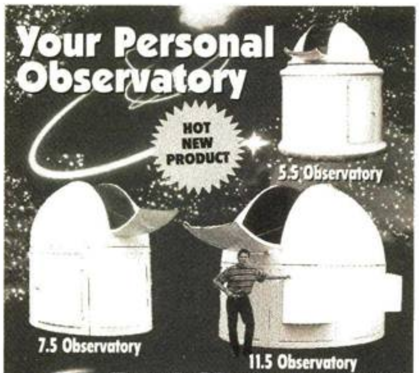

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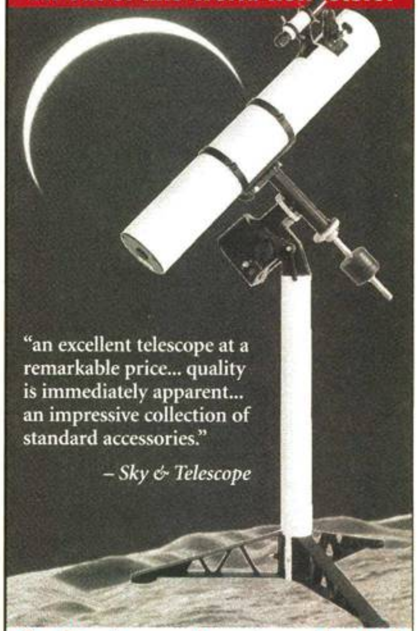

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The aurora borealis dances over the moonlit mountains of Denali National Park, Alaska.

MARCH 1; APRIL 12; MAY 3

The Silicon Valley Astronomy Lecture Series

▶ Smithwick Theater, Foothill College, Los Altos Hills, California. March 1 — Mission to Mars: Exploring the Red Planet; April 12 — The Changing Sun and the Climate of the Earth; May 3 — Cold Hard Worlds at the Edge of the Solar System. 7 P.M. Free. Sponsored by NASA's Ames Research Center, Foothill College, Astronomical Society of the Pacific, and the SETI Institute. Call (650) 949–7888 for more information.

MARCH 2–5

Highlands Stargaze

▶ Nine Mile Grade Campground, Highlands County, Florida. Events include a swap meet, speakers, vendors, a free barbeque, and door prizes. Sponsored by the Highlands Stargazers Astronomy Group. Contact Richard Lindblom, (941) 655–0131; e-mail, lindblom@ct.net; website, http://www.cris.com/~Suz1/Index.shtml.

MARCH 13–17

Lunar and Planetary Science Conference

▶ The NASA Johnson Space Center, Houston, Texas. The meeting will focus on new results in planetary science among researchers in astronomy, geology, geophysics, geochemistry, and petrology. Contact the Conference Administrator, LeBecca Simmons, LPI Publications and Program Services Department, 3600 Bay Area Boulevard, Houston, TX 77058; (281) 486–2158; e-mail, simmons@lpi.jsc.nasa.gov.

MARCH 25

Astronomical Association of Northern California (AANC) Symposium — A Date with the Universe

▶ California Academy of Sciences, Golden Gate Park, San Francisco, California. For more information, visit the AANC website, http://www.lhs.berkeley.edu/sii/aanc/aanc.html; contact AANC president Jane Houston, 167 Dominican Drive, San Rafael, CA 94901; (415) 453–2885; or e-mail, jane@whiteoaks.com.

MARCH 31–APRIL 2

Telescope Optics Workshop

▶ Western Washington University, Bellingham, Washington. The theme this year is Maksutov-Newtonian Telescopes. Contact Kreig McBride, 402 East Horton Road, Bellingham, WA 98226; e-mail, kmcbride@memes.com; website, http://www.wwu.edu/~skywise/optics.html.

APRIL 2–4

Messier Marathon/Star Party

▶ Kalar Kahar, Pakistan. Sponsored by Lahore Astronomical Society. For more information, contact Omer Bin Abdul Aziz by telephone at 092–42–583–1727 or 092–42–583–3838; e-mail, pulsar@brain.net.pk; or view the Lahore Astronomical Society website, http://www.geocities.com/Broadway/8701/.

APRIL 6–9

Peach State Star Gaze

▶ Camp McIntosh, Indian Springs State Park, Georgia. Featuring Antonín Rükl of Prague, Czech Republic, author of *Atlas of the Moon.* For information, contact Ken Poshedly, 1741 Bruckner Court, Snellville, GA 30078; (770) 979–9842; e-mail, ken.poshedly@mindspring.com; website, http://aac.cjb.net.

APRIL 16

Northeast Astronomy Forum and Telescope Show

▶ Rockland Community College, Suffern, New York. Sponsored by the Rockland Astronomy Club. Contact Don Urban, 73 Haring Street, Closter, NJ 07624; (201) 768–6575; e-mail, DonaldUrban@Juno.com.

APRIL 26–29

Mid-South Star Gaze

▶ The Rainwater Observatory and

Planetarium, near French Camp, Mississippi. For more information or to register, phone (601) 547–6865 or you may visit the observatory's website, http://rainwater.astronomers.org.

APRIL 30–MAY 7

Texas Star Party

▶ The Prude Ranch, Fort Davis, Texas, twelve miles from the McDonald Observatory. Contact the Texas Star Party Registrar, 1326 Mistywood Lane, Allen, TX 75002; e-mail, kastro@aol.com; website, http://www.metronet.com/~tsp/index1.html.

MAY 4

Space Day/Cyber Space Day — Living and Working in Space

▶ National Air and Space Museum, Washington, D.C. This day-long event celebrates the extraordinary achievements and opportunities of space exploration. This special day encourages people of all ages from around the globe to advance science, math, and technology education with the goal of inspiring future generations to continue the vision of our space pioneers. For more information, visit the website, http://www.spaceday.com.

MAY 5–8

Astronomy Camp for Adults

▶ Mount Lemmon and Bigelow Observatories, University of Arizona, Tucson, Arizona. Contact Don McCarthy, 933 North Cherry Avenue, Tucson, AZ 85721-0065; (520) 621–4079, e-mail, dmccarthy@as.arizona.edu; website, http://ethel.as.arizona.edu/astro_camp.

MAY 6

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▶ Wesleyan University, Middletown, Connecticut. For more information, contact the Astronomical Society of Greater Hartford, P.O. Box 2271, Hartford, CT 06145-2271; (860) 521–0474; e-mail, vega154@aol.com; website, www.cshore.com/royce/asgh. ◼

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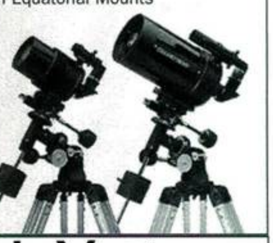

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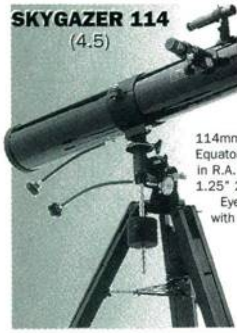

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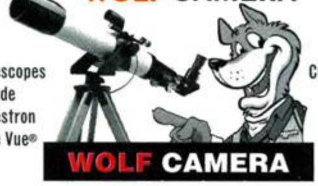

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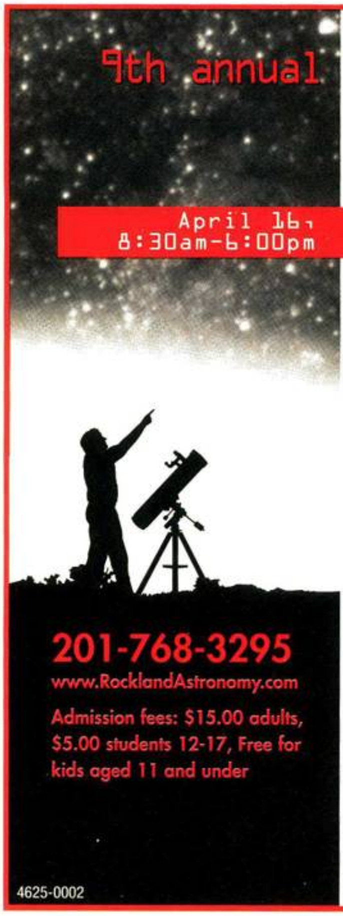

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NEXT month in Astronomy

NASA/STScI

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Planetary nebulae have nothing to do with planets — they are death shrouds for sunlike stars. Astronomers are finally learning how these intricate and colorful gas clouds come to be.

GALAXIES GALORE

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A STRANGE MATTER

Strange seems an appropriate word to describe this exotic form of matter, which physicists think could dominate some pulsars.

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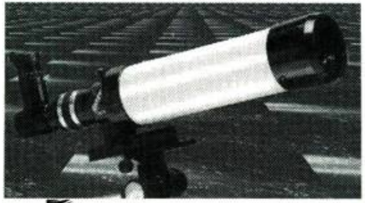

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METEORS

Leonids Were a Hit-or-Miss Show

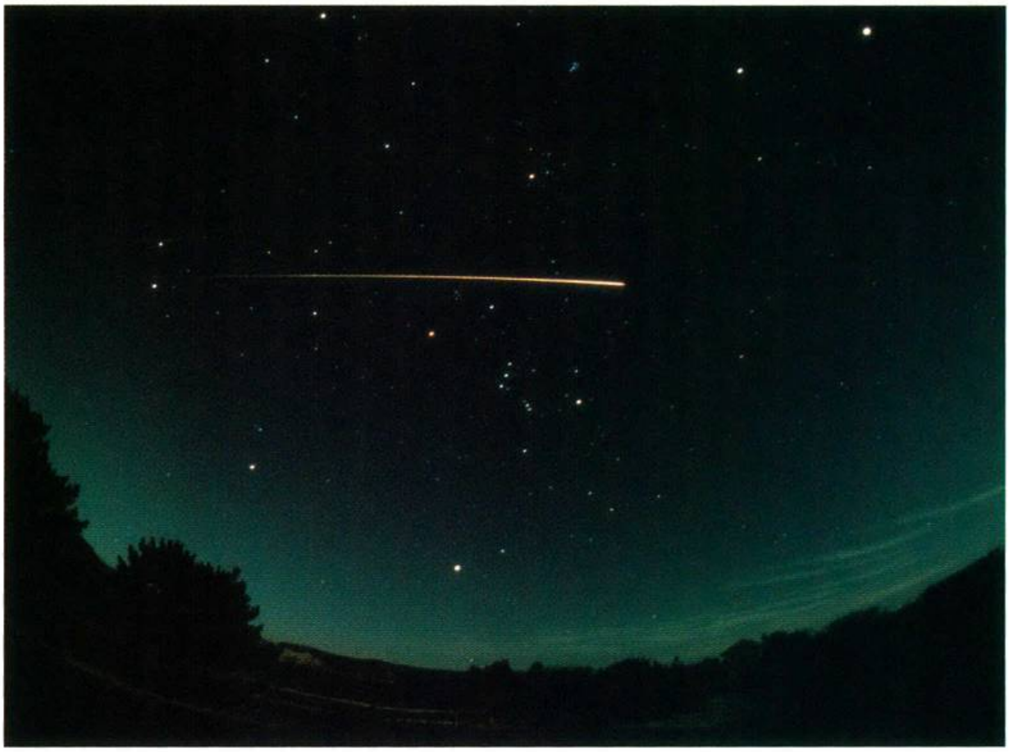
▶ *The International Astronomical Union reported the peak of the 1999 Leonid shower to have been on November 18, at 2:05 UT. The greatest activity was around the Mediterranean Sea, where astronomers tallied 50 meteors a minute. The prediction of David Asher of Armagh Observatory and Rob McNaught of the Australian National University of a strong shower peaking at around 2:08 A.M. UT was therefore quite accurate. Their forecast for faint meteors as opposed to the bright fireballs of last year also proved true. The duo's prognostications call for strong activity in 2001.*

As for my viewing experience . . . I didn't dare go back to bed (again). My dad got me out of bed for the 1966 shower. I was eleven. We stood in the frost at 3:30 A.M. until maybe 4 A.M. We saw no meteors in a deep black, crystal-clear sky. We gave up and went back to bed. Half an hour later, the sky began to fall.

This time, every time I saw a meteor, I thought, "Is it beginning?" But nope, it wasn't.

On the bright side, the model of Leonid performance by McNaught and Asher seems well supported by the behavior of this year's show, abysmal as it was for North America. That model promises a good display in 2001.

— David Cortner,
North Carolina



Long Leonid

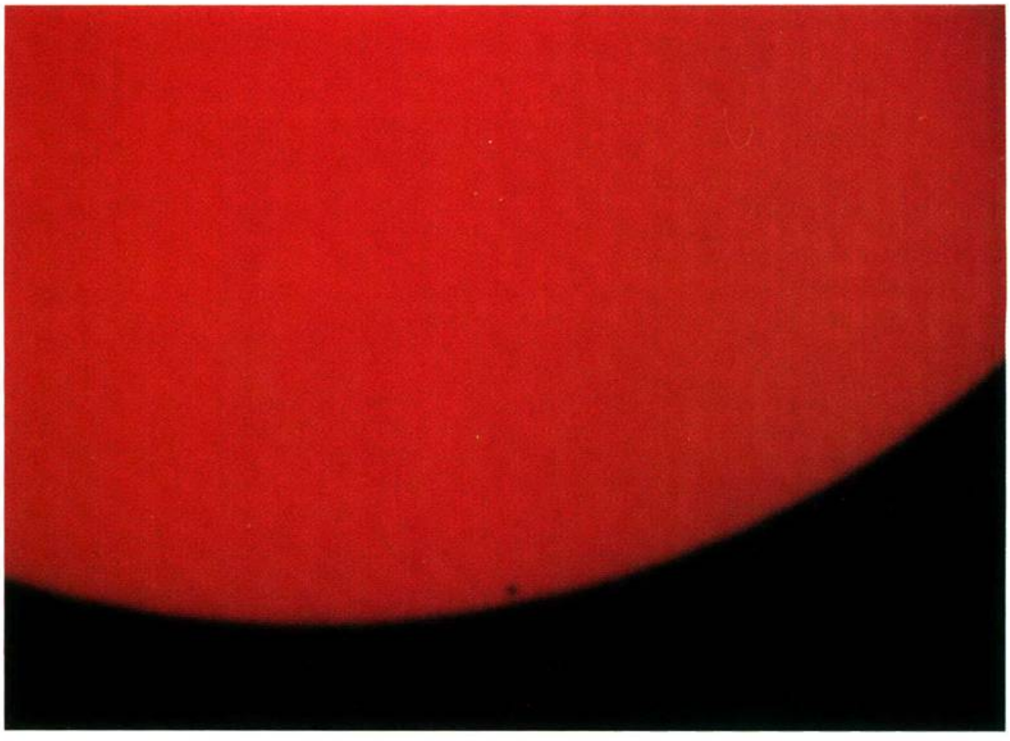
JOHN COSTELLO

(16mm lens at f/4, 3-minute exposure taken 12:30 A.M. EST, November 18, 1999, from New Jersey)

Mercurial Interloper

ROBERT SLOBINS

(8-inch f/10 SCT, Hα filter, taken November 15, 1999)



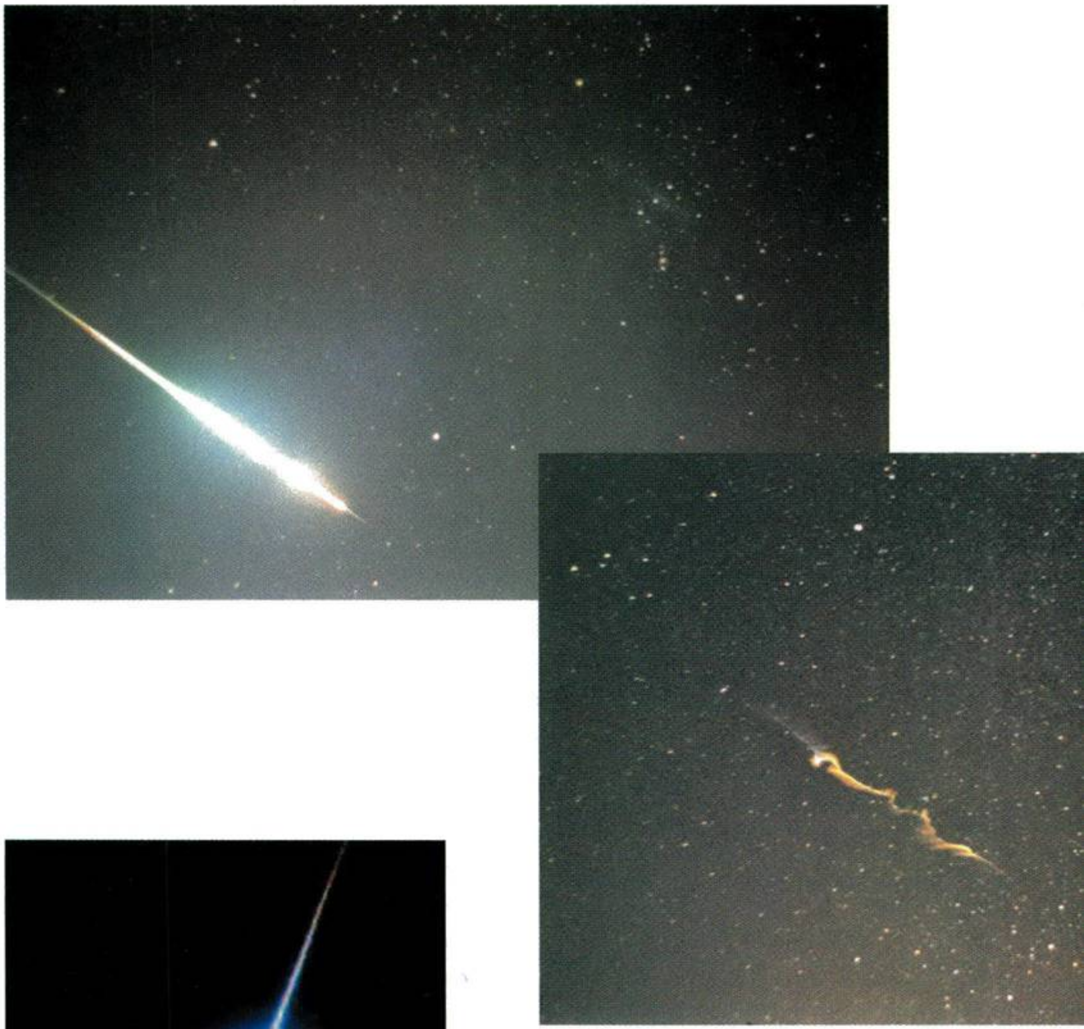
I was one of about 20 people who gathered in Southold, New York, to view the event from Peconic Dunes County Park, a reasonably dark site with a naked-eye limiting magnitude of 6. Half of my fellow meteor watchers were members of the undergraduate astronomy course that I teach at Suffolk Community College. I had assigned class members to observe the Leonid Meteor shower for at least one hour.

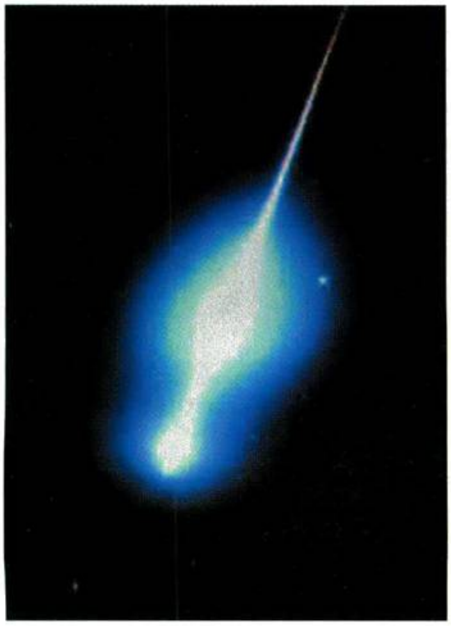
As people began to trickle in, clouds moved rapidly across the sky, with little relief in sight. But things began to clear out around 11:15 P.M. EST, and by midnight the sky was completely cloudless. The temperature also dropped, bottoming out at about 28° F.

The greatest activity that I witnessed was outbursts of eight meteors over 10-minute spans, which is certainly far better than the Leonids normally produce.

The Zenithal Hourly Rate figures seem to agree with reports from Europe and the Middle East that the Leonids peaked before the radiant had risen above the horizon from North America (and, in my case, above the clouds). By the time the United States and Canada had our turn, the event was on the downturn.
— Phil Harrington,
New York

The show started around 1:00 UT with a big fireball low above the sea. At the maximum, around 2:00, the meteors came at a rate of about one every two seconds, often in pairs. Orion was showered with them, along with Ursa Major, to a lesser extent. Our estimate was around 1,200 to 1,800 for the hour of maximum.

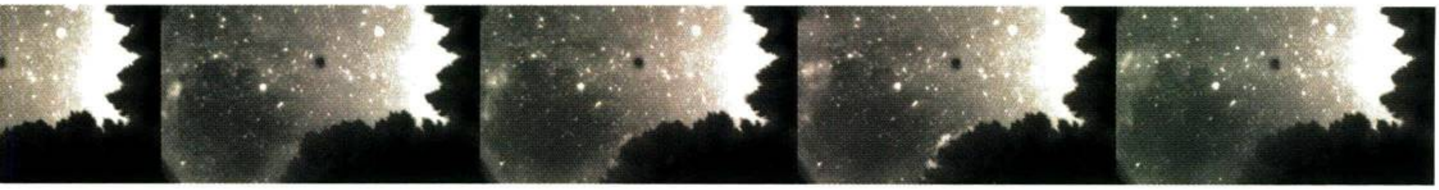




Bolide Scratches the Pole Star

HAMID BARZEGAR

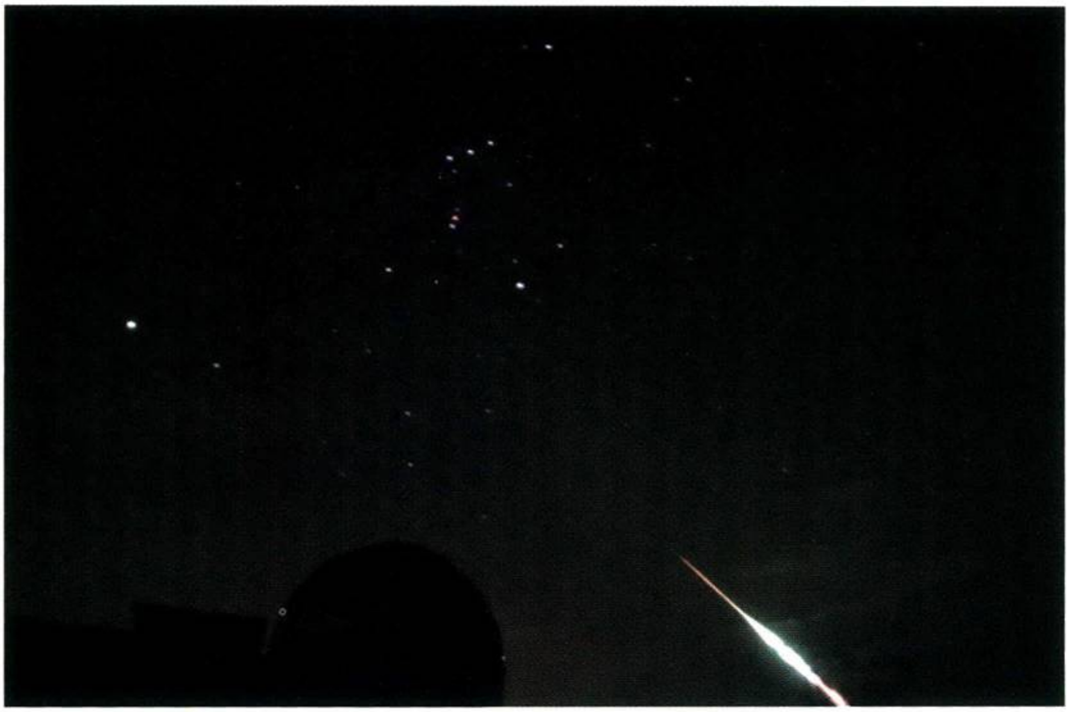
(28mm lens, Fuji 100 film,
30-second exposure taken 1:30 A.M. UT
November 18, 1999, from central Iran)



Fading Fireball

RICHARD BERRY

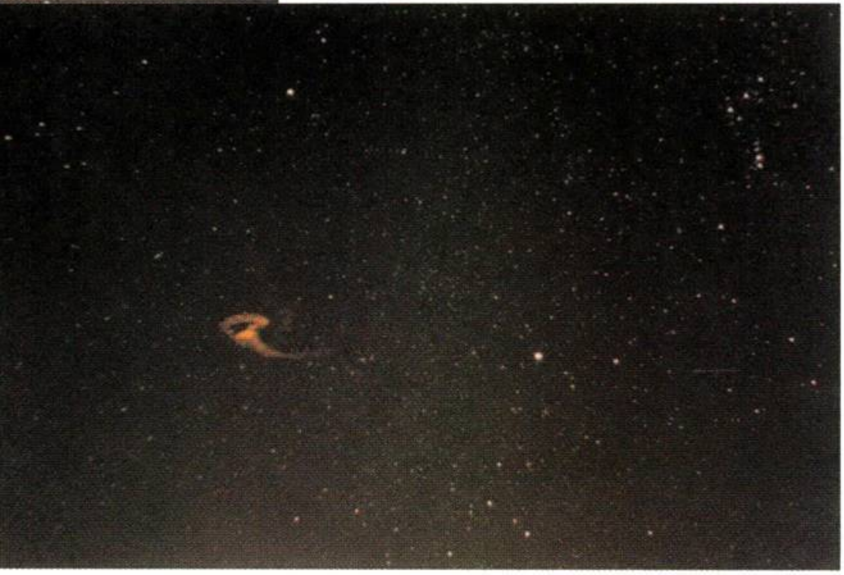
Cookbook 245 CCD camera, 35mm fisheye lens at f/1.5, 120-second intervals. To view the entire video, go to: http://wvi.com/~rberry/Leonids.htm.



Meteor Diving into Clouds

FABIO FALCHI

(24mm lens at f/2.8, Fujichrome 800 film, 2-minute exposure taken 1h 57m UT on November 18, 1999, from Italy)



Leonid Breakup

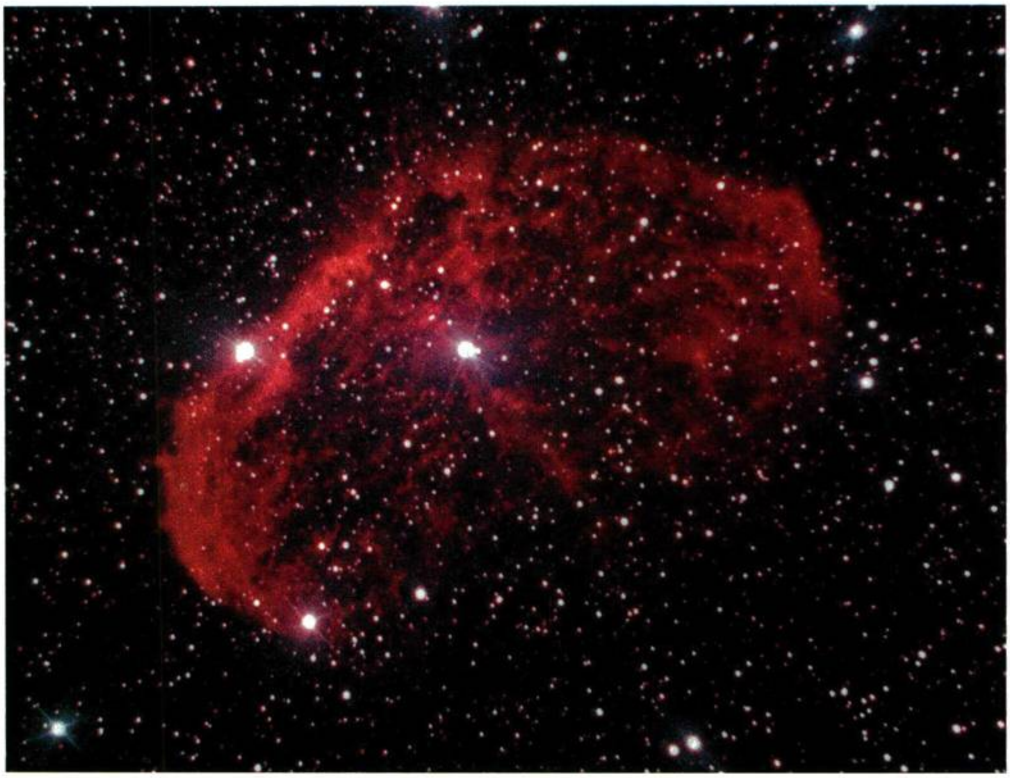
MASSIMO CHIANESE AND CLAIRE ARBONNIER

(29mm lens at f/2.8, Fujicolor Superia 800 film, taken 1h 56m UT on November 18, 1999, from Italy)

A bright fireball soared across Alkaid and left a trail that lasted a few minutes. But the biggest event was a blinding fireball about 2:00 UT [captured by three photographers on pages 124–5]. It illuminated the landscape and left a cloud that lasted more than 30 minutes.

We were lucky to be able to witness such a grand show despite the light pollution from Nice and the neighboring towns.
— Antoine Gerhardt and Michel Benvenuto, France

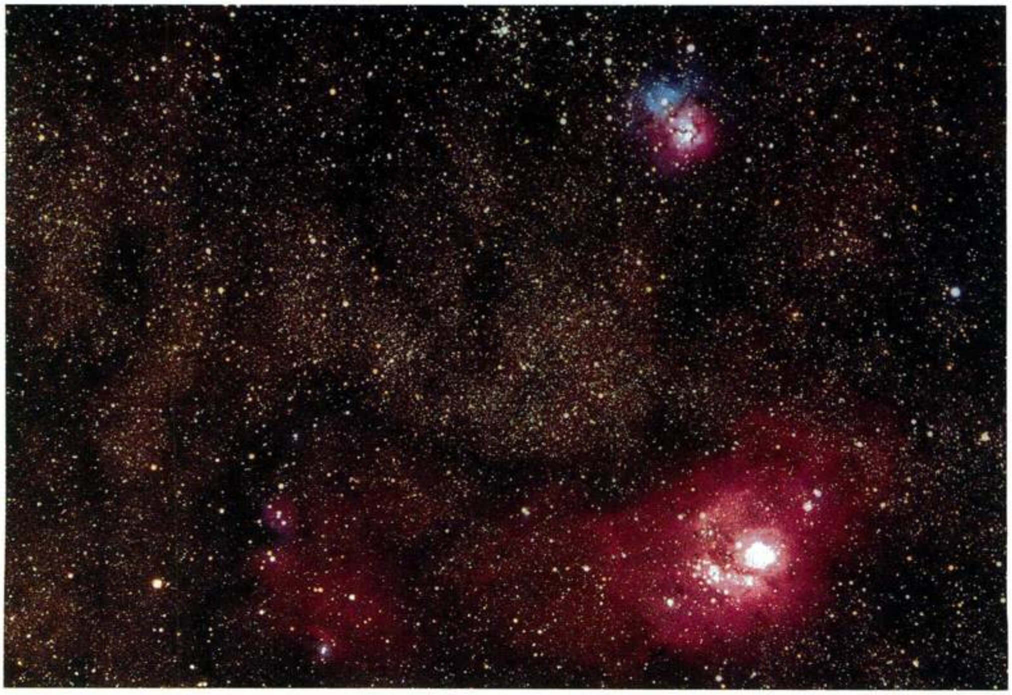
I witnessed a once-in-a-lifetime event with the 1999 Leonid meteor shower. I was in the Saudi Arabian desert dunes near the Persian Gulf. It was a gloriously clear sky. I planned my observing for after 1 A.M. — after moonset. The expected shower seemed to be a fizzle, but I was enjoying scanning some favorite clusters and nebulae with binoculars. At 2:30 A.M., after seeing only 10 to 20 meteors per hour, I went back to my 4x4 to take a short nap. I awoke at 4 A.M. and noticed that the shower had picked up to about 60 per hour. The Leonids were extremely swift and left a good ion trail. At about 4:25 A.M. the floodgates opened, and I began counting 100 meteors per 3-minute interval until I left at dawn. They ranged from barely visible 6th magnitude to a couple of fireballs rivaling Venus (on the eastern horizon) at magnitude –4. The fireballs each ended with a flash explosion. I saw as many as eight meteors in one second and as many as four simultaneously. I am estimating that the rate got up to 5,000 per hour if one could count them all. I can't wait for another event like it.
— Doug Cook, Saudi Arabia



The Crescent Nebula (NGC 6888)

KEN BLANKENSHIP AND DENNIS BATIS

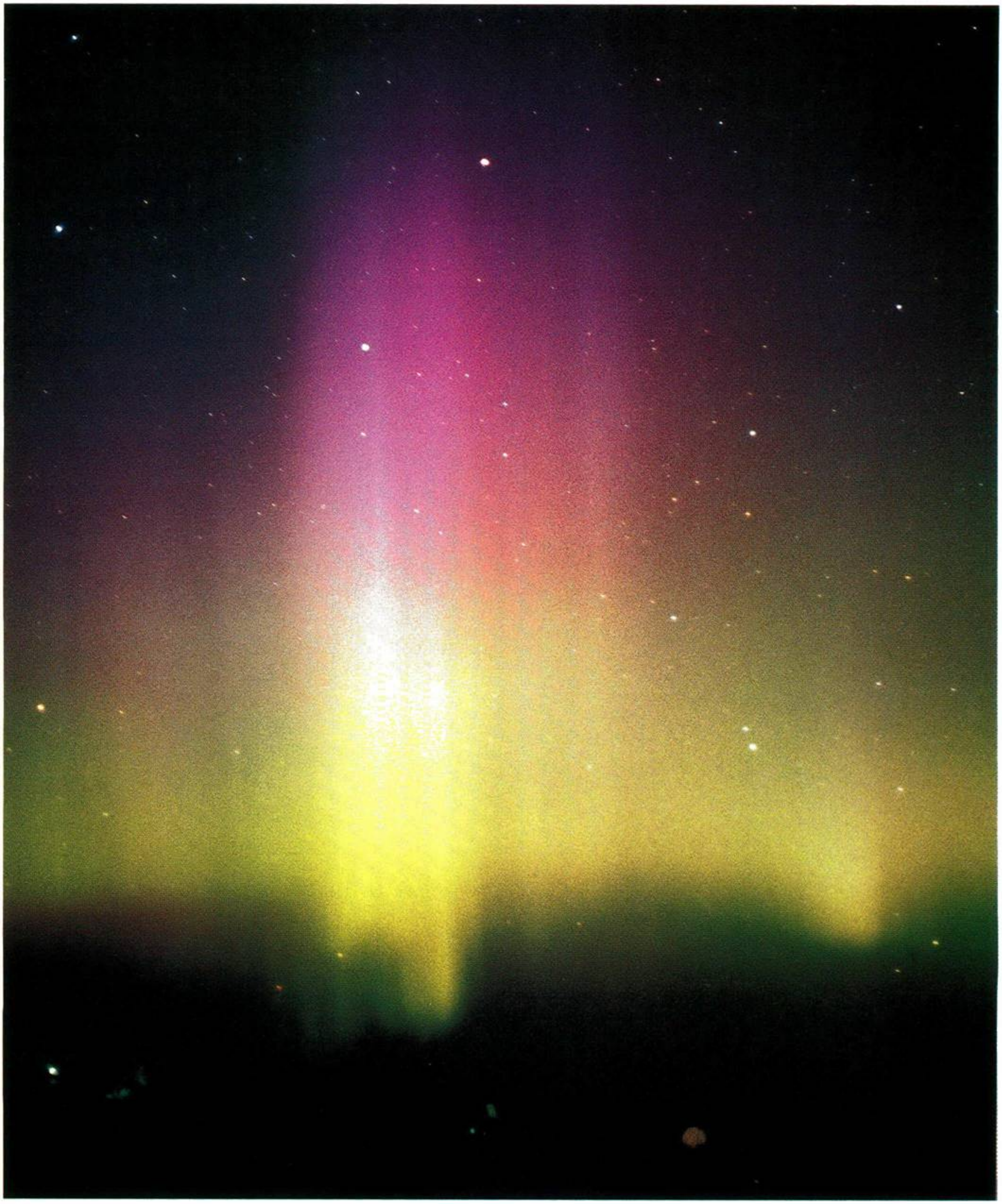
(14-inch SCT at f/7.5, Lumicon Skyfilter, Kodak PJ-400 hypered film, 180-minute exposure)



The Lagoon Triangle (M8, M20, NGC 6559, IC 4685, IC 1274–5, NGC 6546, and M21)

CHRIS COOK

(85mm refractor at f/5.6, unhypered 35mm Kodak Pro PPF 400 film, composite of three 30-minute exposures)

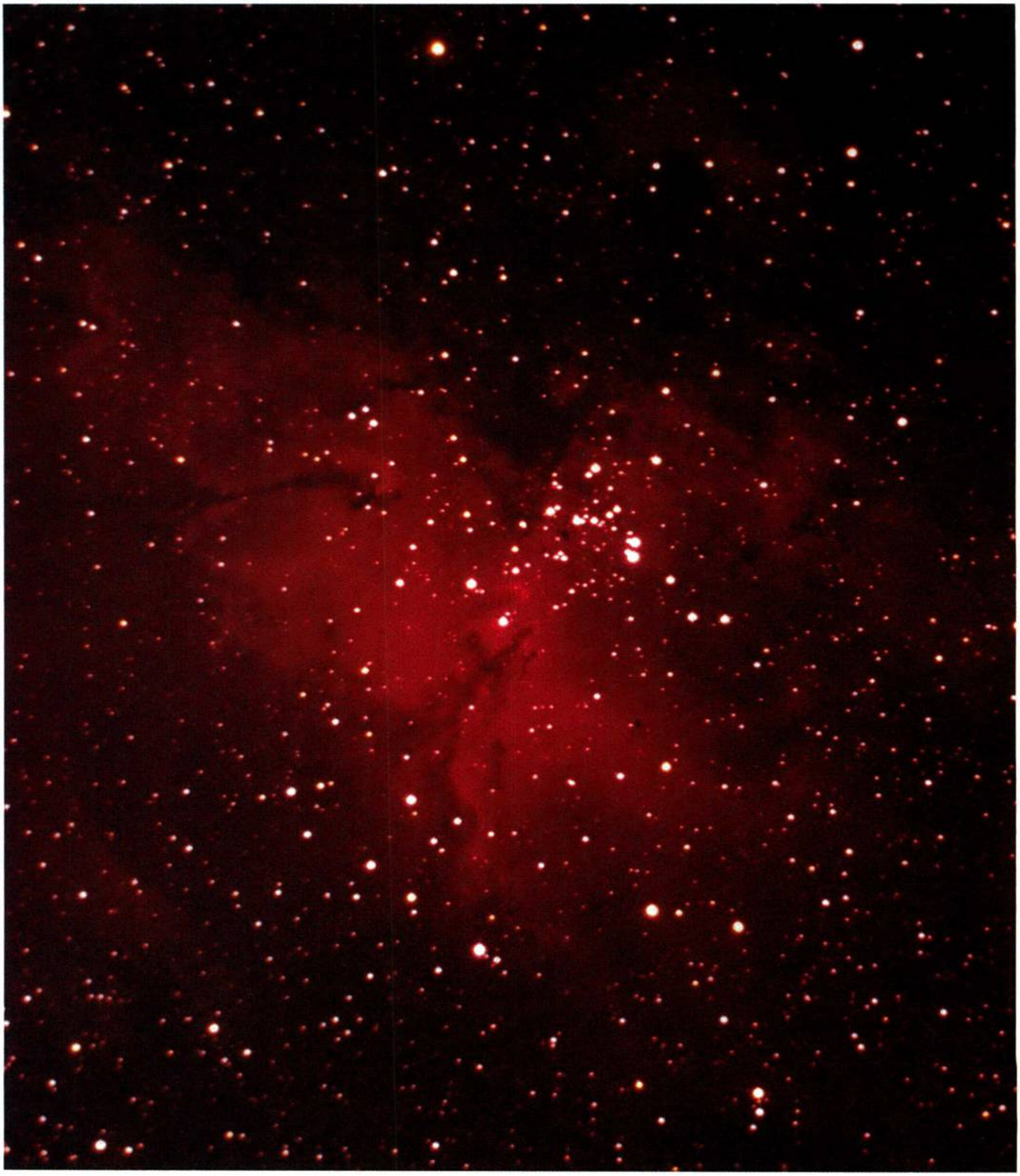


Summer Aurora

JAY BRAUSCH

(50mm lens, Fuji film, taken July 12, 1999)

This month's best astrophoto



The Eagle Nebula (M16)

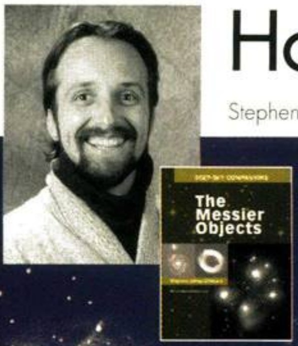
COLT AND PEGGY BEDNORZ

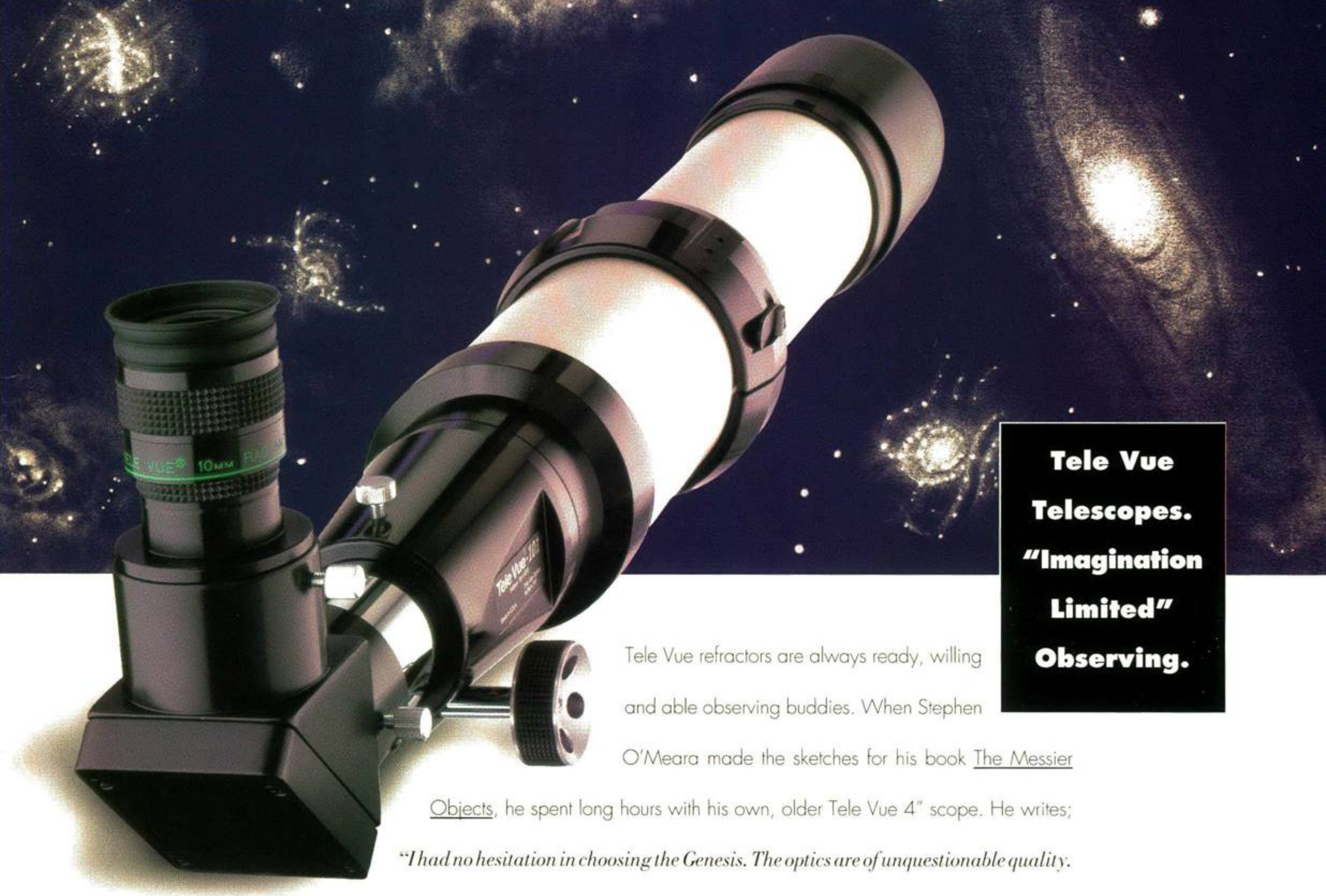
(11-inch SCT at f/6.5, hypered PPF 400 film, 55-minute exposure)

The Eagle Nebula is an emission nebula, a cloud of gas and dust producing a star cluster in Serpens.

How a leading expert chose Tele Vue

Stephen James O'Meara, author, Sky & Telescope editor and first to visually recover Halley's comet. Drawings by Stephen James O'Meara





Tele Vue Telescopes. "Imagination Limited" Observing.

Tele Vue refractors are always ready, willing and able observing buddies. When Stephen O'Meara made the sketches for his book The Messier Objects, he spent long hours with his own, older Tele Vue 4" scope. He writes; *"I had no hesitation in choosing the Genesis. The optics are of unquestionable quality. When coupled with Tele Vue eyepieces (equally revolutionary designs), the Genesis transcends the traditional limitations of long-focus and rich-field refractors, combining the best qualities of both. Genesis and I met serendipitously under dark Texas skies, where I realized its quality and potential. The rest is history."* Stephen discovered a primary virtue of all Tele Vue scopes - versatile performance. Take one along for "imagination limited" observing.

Tele Vue 101: flat field APO, f/5.4

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Located near the northern border of Sagittarius, the Swan (or Omega) Nebula is one of the most prominent of the diffuse nebulae. Discovered by Charles Messier in 1764 and placed into his catalog as its seventeenth object, the Swan Nebula was determined spectroscopically to be a mass of glowing gas, and not simply an unresolved cluster of stars, by Sir William Huggins in 1866. This image, one of the most detailed ever obtained of M17 with any telescope, amateur or professional, is by Jason Ware with a Meade 16" LX200 Schmidt-Cassegrain. Two 60-minute exposures on hypered Kodak PPF 400 film were scanned, digitally combined, and processed to obtain the final image shown here.

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